ORDER

6750.16C

SITING CRITERIA
FOR
INSTRUMENT LANDING SYSTEMS

October 31, 1995

U.S. DEPARTMENT OF TRANSPORTATION
FEDERAL AVIATION ADMINISTRATION

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RECORD OF CHANGES

DIRECTIVE NO. Order 6750.16C

CHANGE TO BASIC	SUPPLEMENTS			OPTIONAL USE	CHANGE TO BASIC	SUPPLEMENTS			OPTIONAL USE

FAA Form 1320-5 (5-68) SUPERSEDES PREVIOUS EDITION

FOREWORD

This order is a complete revision of Order 6750.16B. It has been updated to reflect current systems and equipment in the FAA inventory as well as the latest practices and criteria.

Loni R. Czekalski

Loni R. Czekalski
Director of Communications, Navigation,
and Surveillance Systems, AND-1

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CHAPTER 1. GENERAL INFORMATION

1. **PURPOSE.** This order provides guidance to engineering personnel engaged in the siting of Federal Aviation Administration (FAA) instrument landing systems (ILS). Sufficient information, supplemented by relevant drawings, will enable the engineer to select the optimum site, within defined limits, for each of the subsystems which comprises a Category I, II, or III ILS.

2. **DISTRIBUTION.** This order is distributed to the team level in the Integrated Product Team , GPS and Navigation, to the division level in the offices of Airport Safety and Standards, Flight Standards, NAS Operations, Operational Support, Requirements and Life-Cycle Management, Resources Management, Systems Engineering, and Air Traffic Plans and Requirements Services in Washington headquarters; to branch level in the regional Airway Facilities Division and to the Airway Facilities (AF) General National Airspace System (GNAS) sectors, sector field offices, sector field units and sector field office units.

3. **CANCELLATION.** Order 6750.16B, Siting Criteria for Instrument Landing Systems, dated June 17, 1985 is canceled.

4. **EXPLANATION OF CHANGES.** This is a complete revision of the canceled document.

5. **APPLICATION.** The criteria set forth in this handbook apply only to new establishments or relocated facilities. Changes to existing facilities for the sole purpose of obtaining compliance with this criteria are not required.

6. **DIRECTIVE VERBS.** The material in this handbook contains FAA criteria, recommended practices, and other guidance material which require the use of certain directive verbs such as **SHALL**, **SHOULD**, **WILL**, and **MAY**. In this handbook the explicit meaning of the verbs is as follows:

a. SHALL. The action is mandatory. For example: "The localizer station **SHALL** automatically shutdown if the monitor detects an out-of-tolerance condition."

b. SHOULD. The action is desirable or recommended. For example: "The glide slope **SHOULD** be located 400 feet from the runway centerline."

c. WILL. The action is to be taken in the future. For example: "Some facilities **WILL** be programmed for upgrading to provide Category II performance."

d. MAY. The action is permissible. For example: "Since a capture effect system requires a higher antenna mast than a null reference system, a greater lateral distance **MAY** be required."

7. **PROCEDURES.**

a. Safety. Personnel shall use care in working on ILS equipment, particulary radio transmitters since the voltages present are dangerous to life. Oberservance of precautions necessary to avoid electrical shock is the direct responsibility of the individual. No one shall perform work on the equipment without full knowledge of the dangers involved. Work on high voltage circuits should not be attempted by an individual when it is possible to obtain the sevices of an assistant.

b. Standards and Tolerances. The standards and tolerances for ILS are contained in Order 6750.49 Maintainence of Instrument Landing Systems (ILS) Facilities, and the applicable instruction books. Note that for installation purposes the initial tolerances shall apply.

8. INTRODUCTION.

a. The ILS provides guidance to pilots of properly equipped aircraft to assist them in landing safely under conditions of reduced ceilings and lowered visibility. The use of an ILS materially aids the service to airports under all weather minimums.

b. ILS's are categorized according to the minimum visibility conditions under which aircraft landings are permissible. The criteria specified in this handbook apply to Category I, Category II, and Category III ILS's.

c. One of the goals of the FAA is to provide an all-weather ILS which, with the possible use of ancillary equipment, will provide information sufficient to guide the aircraft down to the runway and along the runway surface regardless of weather minimums. The ability to attain this objective depends to a great extent on the proper siting and performance of each ILS subsystem.

9. ILS ESTABLISHMENT CRITERIA.

a. ILS establishment assignments are made by the Washington office from regional office selection and, in accordance with the current ILS establishment policy, shall be supported by a fully documented staff study including a benefit/cost analysis. Consideration is also given to the reduction in the existing weather minimums which an ILS will permit. At some locations other factors may preclude any improvement in the minimums; however, the assignment may be approved on the basis of the improved margin of safety provided by an ILS.

b. The particular runway which the ILS will serve must be selected in conjunction with the airport assignment. This choice is based on the following considerations:

(1) Runway length and width.

(2) Compliance with the minimum obstruction clearance criteria.

(3) Alignment with respect to the prevailing low visibility wind.

(4) Orientation with respect to the traffic procedures of the airport and airway concerned.

(5) Missed approach procedure.

c. The location of the electronic systems must also be considered when making the ILS runway selection.

It is impractical to designate a runway for the establishment of an ILS without giving consideration to the physical space requirements, accessibility, and the operating environment for each of the subsystems. When these factors appear to negate the establishment of an ILS, the cost of providing satisfactory facility locations shall be weighed against the improvement in weather minimums, safety, and service that the ILS (or partial ILS consisting of a localizer and an outer marker) will provide.

d. The newer ILS localizer antenna systems will not provide a usable back course. If an instrument approach is required in that direction, other means must be provided, such as a facing localizer on the opposite end of the runway or an 8 or 14 element V-Ring array or a terminal very high frequency omnidirectional range (TVOR).

10. OBSTRUCTION CRITERIA. Obstruction standards specified in FAR Part 77, Subpart C shall be used to determine required obstruction clearance surfaces. If it is feasible to design and install an ILS component (except glide slope) without penetrating an FAR Part 77 surface, do so. However, if the only feasible siting involves penetrating an FAR Part 77 surface, that siting does not require a waiver but does require airspace review and approval. In any case, siting an ILS component must not violate required obstruction clearance as specified in the latest edition of Handbook 8260.3, United States Standard for Terminal Instrument Procedures (TERPS).

11. NATIONAL AIRSPACE SYSTEM CHANGE PROPOSAL (NCP). If in the process of planning or locating the ILS facilities it is determined that the siting criteria set forth in this order cannot be followed, an NCP shall be submitted in conformance to the latest edition of Order 1800.8, National Airspace System Configuration Management. An NCP to a siting criteria shall be requested a minimum of 60 days prior to the start of construction.

12. GENERAL DESCRIPTION OF THE ILS. The ILS provides the aircraft with three basic types of navigational information as outlined below. Other aids may also be provided to supplement the ILS.

a. Lateral guidance information indicates to the aircraft whether it is to the right, left, or aligned with the approach course line. This information is provided by the ILS localizer.

b. Vertical guidance information indicates the aircraft position above, below, or along the proper descent angle towards the runway touchdown point. The ILS glide slope provides this information.

c. Distance information indicates the aircraft's approximate distance from the runway threshold. This information is provided indirectly by the ILS outer, middle, and inner markers in conjunction with the applicable instrument approach procedure chart, and directly by distance measuring equipment (DME) located at the localizer site.

d. Supplementary Aids. Compass locators are sometimes provided at one or both of the marker sites to assist the aircraft in locating the ILS course. Other types of navigational aids may also be used for this purpose. Approach lighting systems with sequenced flashers and other visual aids are usually provided to work in conjunction with the ILS.

e. Monitor and Control Equipment. Each ILS component is continuously monitored at the site with automatic equipment provided to shut down the facility if the signal parameters exceed established limits. Status indicators, located at the control tower or other manned FAA monitoring locations, provide air traffic control (ATC) personnel with an indication of the system status at all times except when the status unit is located in a facility which is not manned 24 hours per day. At these locations, the ILS continues to operate, but the particular airport cannot be designated as an alternate flight terminus during the period of time the ILS components are not being remotely monitored. At some locations, remote control equipment is also provided to turn the equipment on and off from the remote monitor point. (See paragraph 45b for remote monitoring of ILS.)

f. Remote Maintenance Monitoring. Some ILS equipment provides for remote maintenance monitoring (RMM) capabilities, which allow the maintenance technician to perform most maintenance tasks remotely via a computer. The RMM equipment can either be built in to the ILS equipment, or may be retrofitted to existing ILS equipment (e.g. airport remote monitoring system - ARMS). Most RMM systems are designed to connect with the maintenance processor system (MPS) equipment, and will provide for remote status and control capabilities from a maintenance control center (MCC) at the sector maintenance office (SMO) or an air route traffic control center (ARTCC). Many RMM systems are designed to interface with other equipment on the airport (e.g. airport lighting systems).

13. SITING EFFECTS ON ILS OPERATIONS. The ability of each subsystem that comprises the ILS to provide reliable and accurate guidance information depends primarily upon the proper formation of their respective radiationpatterns. The greatest detriment to the formation of the desirable patterns is the presence of reflecting objects such as uneven terrain, power lines, buildings, dense vegetation, and ground vehicles and aircraft moving in the vicinity of the sites. The following siting requirements for each type of facility should enable the responsible engineer to choose the optimum site.

14. MULTIPLE ILS ESTABLISHMENTS. When planning ILS establishments for airports already having one or more commissioned systems, consideration must be given to the compatibility of the multiple systems in addition to their individual compliance with the standard siting criteria. This compatibility is assured to a great extent by assignment of non-interfering frequencies, distinctly different identification codes, and stringent approach procedures for each of the multiple systems. In addition, the following criteria for each particular configuration of multiple system shall apply (see Figure 1-1 Multiple ILS Configuration).

a. Parallel Approach Systems. For simultaneous approaches, the minimum separation between the two runway centerlines shall be 4300 feet and may be used only when both runways are provided with ILS front-course approaches. The outer markers serving the parallel runways shall be located at their respective glide-slope intercept points. In some instances, the two outer markers serving the parallel approaches are abeam of each other on a common lateral centerline that is perpendicular to both localizer course lines. The markers, whether staggered or abeam of each other, shall be separated sufficiently to preclude interference at altitudes intended for use. If the outer markers interfere at the altitudes intended for their use, the keyed identification of the two markers shall occur simultaneously by the use of a single common keyer, and the operating frequencies shall be separated by 8 kHz (75 MHz + 4 kHz and 75 Mhz - 4 kHz). There is no additional criteria for the middle markers in a parallel approach configuration since the respective patterns at lower heights are non- interfering. The middle markers shall, therefore, be located in accordance with the individual approach requirement.

b. Dual-Facing Systems.

(1) At runways where localizers are established at both ends to provide guidance for opposite approaches, the localizers shall be interlocked so that only one localizer is capable of radiating at any given time and is remotely controlled. A feature may be incorporated into the interlock, however, that will permit the activation of both localizers simultaneously to check the availability of the inactive localizer. This feature shall be operable from the airport traffic control tower (ATCT), and shall automatically prevent simultaneous operation in excess of 30 seconds. The use of the quick feature shall be restricted to periods when there are no approaches to the active runway.

(2) Where discrete frequencies are assigned, simultaneous operation will be permitted for the purpose of facility installation, maintenance, or flight inspection if suitable weather conditions exist and a proper Notice to Airmen (NOTAM) is issued. The minimum weather conditions for such operation are a 1500-foot ceiling and 3 miles visibility. If an ILS not undergoing installation, maintenance, or flight inspection is retained in service, it should be announced through a NOTAM as being unusable from the middle marker to touchdown during the period of simultaneous operation.

(3) The localizer interlock system shall be installed and used to deactivate the localizer that is serving the inactive runway. At no time are both localizers of dual-facing ILS's to be active at the same time except for the situations and conditions contained in paragraph 7b(2).

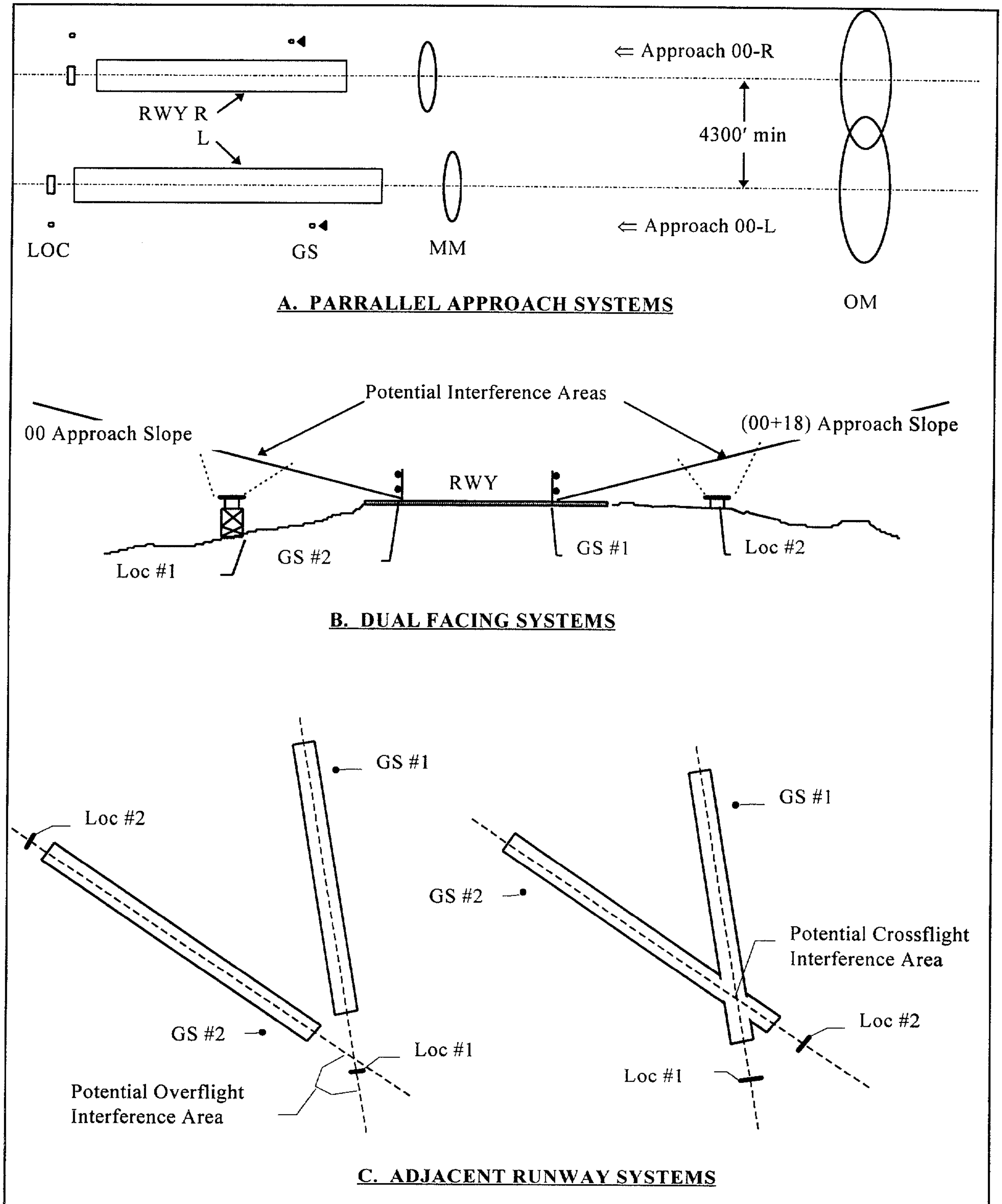


FIGURE 1-1. MULTIPLE ILS CONFIGURATIONS

c. Adjacent Runway System. Interference between localizers serving different runways is also possible depending on the configuration of the runways and the distance between the two systems. When an aircraft on approach to one localizer must pass through a strong radiation field of a localizer serving an adjacent runway, flight inspection will be conducted to determine if unacceptable interference is encountered . If such a determination is made by flight inspection, a positive interlock device shall be installed to prevent both systems from being energized simultaneously from the remote control point.

d. ILS's That Use A Common Frequency. ILS's that use common frequencies shall have an interlock to prevent simultaneous operation of the localizers and glide slopes from the remote control point. These ILS's shall not be active at the same time except when active maintenance work is being performed and:

(1) The unselected system is connected to a dummy load and prior verification by flight inspection indicates that no stray radiation exists that will interfere with an aircraft passing over the localizer on an approach.

(2) If radiation from the antenna system is required, the work shall be performed only during visual flight rules (VFR) weather and a NOTAM is issued stating that both ILS's are out for maintenance.

e. Interlock Activation Delay. The ILS interlock system shall have a 20-second time delay. The delay is from the time the active ILS shuts down to the time the newly selected ILS activates.

15. ILS CRITICAL AREAS.

a. Definition. A critical area is a zone encompassing a specific ground area in the vicinity of a radiating antenna array which must be protected from parking and the unlimited movement of surface and air traffic to ensure the continuous integrity of the signal received by the user aircraft. These zones are referred to as the localizer critical area and the glide slope critical area, respectively. The critical area is intended to protect the ILS facility from moving aircraft and vehicles. While buildings or other structures should not be allowed in the critical area unless absolutely necessary, placing a building ouside the critical area will not guarantee non-interference with the ILS signal in space. The possible deleterious effects of permanent structures or other objects to be placed in the critical area should be analyzed and or mathematically modeled or if after the fact, a confirming flight inspection shall be conducted to determine the effects, if any, on the ILS sub-systems.

b. Localizer Critical Area. The actual critical area dimensions and the corresponding protection requirements depend on several factors. These include, for example, size, numbers, and orientation of signal interfering aircraft, localizer course width, category of operation, and antenna directional characteristics.

(1) The area defined in figure 1-2 is the critical area.

(2) The category II/III critical area dimensions shown in figure 1-2 are based on the assumption that the entire longitudinal axis of the aircraft must be clear of the critical area.

(3) Category II/III two-frequency localizer may have taxiways as close as 250 feet from the runway centerline, as long as the aircraft will be taxiing parallel or at an angle less than 30 degrees from the runway centerline and the obstacle free zone is protected.

(4) Installation of the localizer antenna system on an elevated platform does not negate the requirements of the critical area.

(5) Category II or III installations are not authorized using eight-element antenna arrays as the critical areas become too large to protect.

c. Glide Slope Critical Area. As in the case of the localizer, the actual size of the glide slope critical area is affected by several factors including type of radiating array, category of operation, and interfering aircraft size and orientation.

(1) The critical area for image glide slopes is identified in figure 1-3 by pentagon EFGHJ. The size of the critical area shall be in accordance with Table 1-1, Glide Slope Critical Area Dimensions.

(2) The end fire glide slope critical area is shown in figure 1-4. It extends from 50 feet behind the rear antenna to the approach end of the runway and from the edge of the runway to a line parallel to the runway which is 50 feet from the nearest antenna element in the direction opposite the runway.

d. Critical Jet Blast Areas. In addition to safeguarding the ILS guidance information from surface traffic interference, the system must be protected from long term deterioration resulting from accumulation of jet engine exhaust residue on the radiating antennas. Since prolonged exposure to jet fumes is dangerous to the health of personnel working on the systems, it is also necessary to minimize this deleterious effect. Therefore, no jet aircraft shall be permitted to park or hold within 600 feet of the ILS equipment shelters, the localizer antenna array, or the glide slope antennas. This distance is measured from the individual ILS component to the nearest aircraft engine, with the latter's jet exhaust directed toward the component.

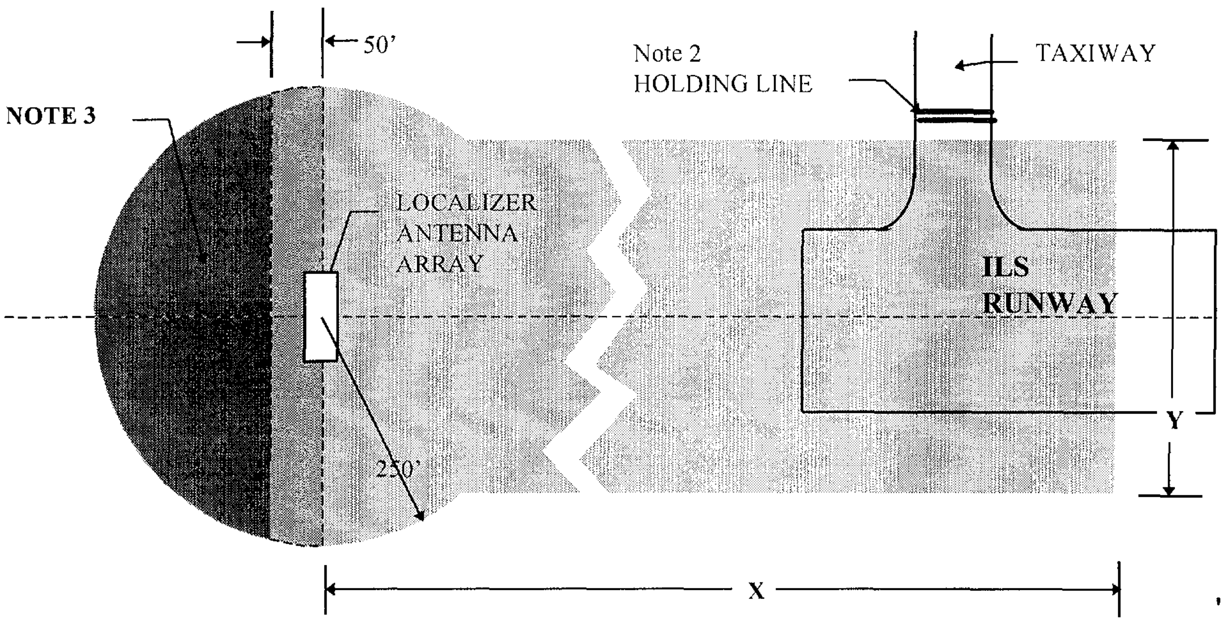
e. Restrictions. Although it is desirable to completely restrict the critical areas and no-parking zone from all surface traffic, this is generally not feasible since access to and from the runway, terminal areas, ramp and hangar areas may necessitate traffic movement through these regions. The restrictions must therefore be sufficiently permissive, as delineated in the following, to permit this traffic flow.

(1) Except as provided below and in the latest edition of Order 7110.65, Air Traffic Control, all surface traffic shall remain clear of the localizer and glide slope critical areas whenever the equipment is in operation. Parking of unattended vehicles or aircraft within this area is prohibited at all times, except for vehicles in use by maintenance technicians which may be parked adjacent to the equipment shelter.

(2) Where roads, highways, railroad tracks, etc., pass through the critical area and investigation indicates localizer degradation results from traffic movement along these routes, effective measures shall be taken to overcome the condition. Such measures include elevation of the array followed by appropriate math modeling or flight inspection or relocation of the facility.

(3) Maintenance vehicles may pass through the critical area along access roads when traveling to and from the equipment shelter provided the route does not pass in the vicinity of the antenna.

f. Vegetation Control. Vegetation growth shall not be permitted to exceed 12 inches in height in the ILS critical areas within 2000 feet of the localizer and 800 feet from glide-slope antennas. Growth of crops of any type shall not be permitted. Mowing operations should be coordinated for a time to coincide with scheduled facility maintenance.



	X	Y	
Category I	2000	400	Note 4
Category II/III	2000	400	Note 5
Category II	4000	500	
Category III	7000	500	

FIGURE 1-2 CATEGORY I, II, & III CRITICAL AREA

Figure 1-2 Notes:

1. Critical area is indicated by shaded zones.
2. Hold line/signs indicate the position beyond which aircraft/vehicles will require ATCT authorization before proceeding on or across runway.
3. The darkest shaded area is deleted from the critical area when a unidirectional localizer antenna is installed. The traveling wave and log-periodic antenna arrays are in this category.
4. For 8-element localizer arrays with course widths less than 4 degrees and runways which operate 747 size aircraft, the Y dimension shall be 600 feet.
5. These dimensions apply where aircraft size is equal to or less than 135 feet in length or 42 feet in height; e.g., 727.

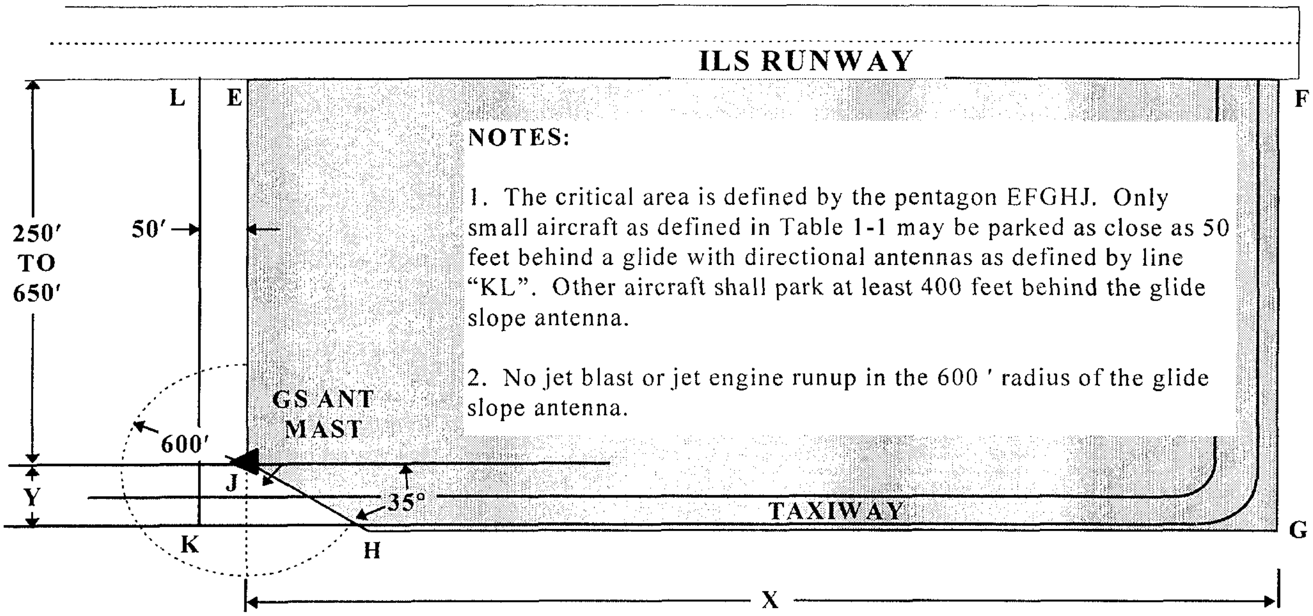


FIGURE 1-3. GLIDE SLOPE CRITICAL AREA

FACILITY TYPE	CATEGORY I		CATEGORY II/III	
ALL GLIDE SLOPES EXCEPT END FIRE	X	Y	X	Y
Small Aircraft 2/	800	100	800	100
NULL REFERENCE				
Medium Aircraft 3/	2000	200	2500	200
Large Aircraft 4/	3100	200	3200	200
SIDEBAND REFERENCE & CAPTURE EFFECT				
Medium and Large Aircraft 3/ 4/	1300	200	1300	200

Notes:

1. All distances are in feet and represent the minimum allowable distances from the nearest point on the aircraft longitudinal axis (line from nose to tail) to the glide slope antenna as defined in figure 1-3.

2. Small aircraft are defined as aircraft with dimensions less than 60' in length or 20' in height; i.e., Kingair. This includes all surface vehicles and helicopters other than jet, turboprop or turbine powered helicopters.

3. Medium aircraft are defined as aircraft larger than small aircraft but less than 160' in length or 38' in height; i.e., B-727, MD-80.

4. Large aircraft are defined as aircraft larger than medium aircraft.

5. The small, medium and large aircraft sizes are based upon the dimension used in computer modeling of critical areas and apply to this document only.

TABLE 1-1 GLIDE SLOPE CRITICAL AREA DIMENSIONS 1/

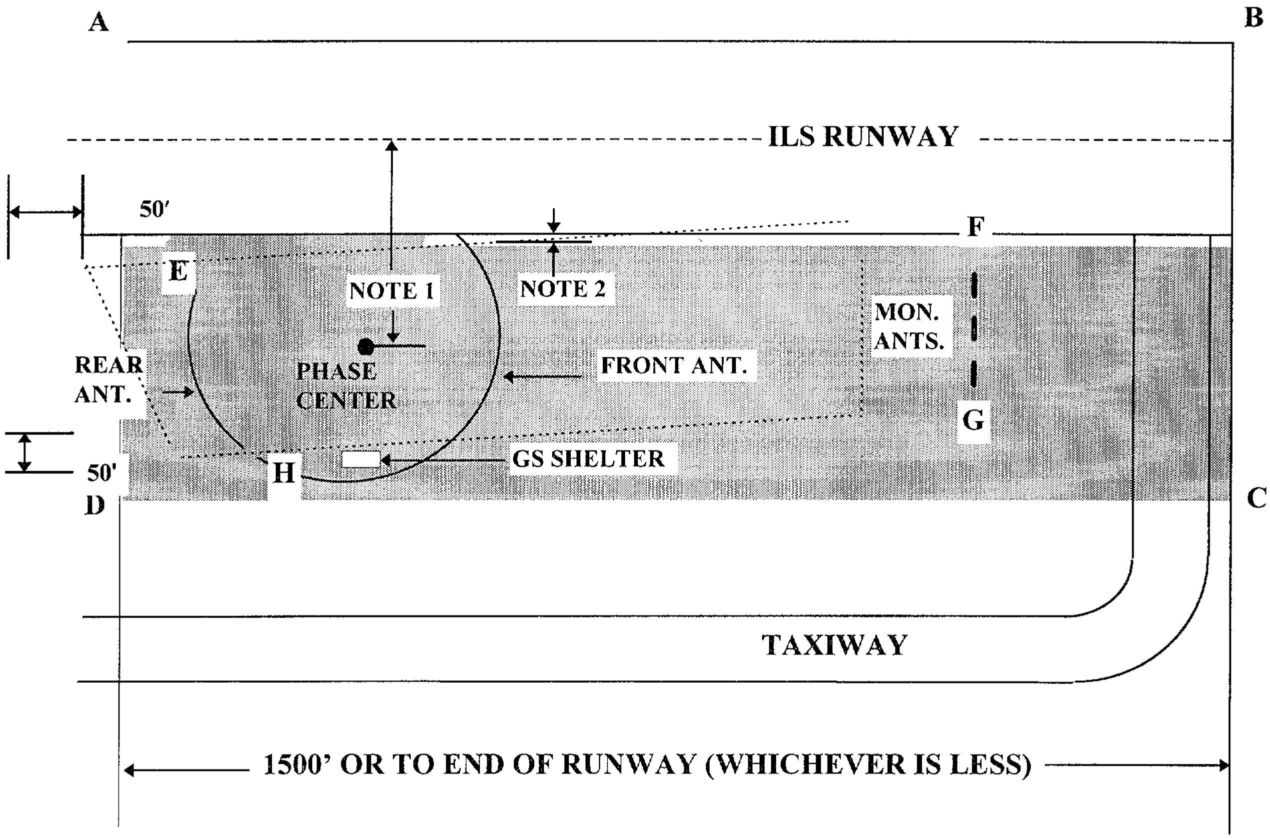


FIGURE 1-4. END-FIRE GLIDE SLOPE CRITICAL AREA

NOTES:

1. This distance is approximately 200 feet, depending on runway width. Refer to FAA drawings D-6226-1 and D-6226-2 for installation layout.
2. This distance shall not be less than 25 feet.
3. Parking of aircraft not permitted within area "ABCD," taxiing or holding aircraft is permitted in unshaded area.
4. No jet blasts or jet engine runup within 600 feet of antennas or equipment shelter.
5. Snow Removal Area "EFGH". (Refer to pararaph 32c.)

g. Implementation. Effective implementation of the critical area restrictions requires a coordinated effort by several regional and field offices as follows:

(1) Airway Facilities.

(a) Advise airport management authorities of these criteria and request that they provide and maintain the necessary signs, holding lines, and other markings delineating the critical areas. In addition, new establishments should be planned to avoid critical area encroachment of existing runways and taxiways if possible. (See latest edition of Advisory Circular 150/5340-1, Standards for Airport MarkingMarking of Paved Areas on Airports, for marking information.)

(b) When advised by Air Traffic that the implementation of this order impacts airport operations or capacity, Airway Facilities shall request assistance from the regional and national office to obtain site specific math modeling or flight inspection of any proposed relaxation of the critical areas.

(2) Air Traffic.

(a) Where an ATCT is in operation, and the airport management has provided the required markings and signs, tower personnel will not clear aircraft or vehicular traffic into the ILS critical areas, except as provided in paragraph 8e in accordance with Order 7110.65, Air Traffic Control,. Order 7210.3, Facility Operation and Administration, and applicable letters to airmen and letters of agreement.

(b) When the implementation of this order impacts airport operations or capacity, the appropriate Airway Facilities office should be notified.

(3) Aviation Standards. Conduct flight checks to ascertain whether the exceptions under paragraph 15e are permissible and provide certification to this effect.

16.-17. Reserved

CHAPTER 2. THE ILS LOCALIZER

18. INTRODUCTION AND GENERAL INFORMATION.

a. ILS localizers operate on one of 40 channels within the frequency band of 108 to 112 MHz. Individual channel assignments are made in accordance with frequency management procedures. Each localizer is assigned a four-letter identification code: an "I", to distinguish the ILS from other navigational aids, followed by a three-letter code which identifies the particular ILS. The identification is accomplished by modulation of the localizer transmitter with a 1020-Hz tone keyed in accordance with the assigned four-letter code at the rate of approximately eight identification signals per minute. Where DME is used in conjunction with the ILS, every fourth localizer identification signal is used to key the DME transponder.

b. The localizer course guidance information is provided by the modulation of the transmitted signal with audio signals of 90 and 150 Hz. The antenna radiation pattern is designed so that the 150-Hz signal is predominant to the right side of the front course approach (shown as the blue zone on the ILS charts), and the 90-Hz signal is predominant to the left of the approach (shown as the yellow zone on the ILS charts). The localizer course itself is a theoretical straight line formed by the locus of the points where equal levels of 90- and 150-Hz signals are received and detected by the aircraft. The localizer course is usually adjusted to coincide with the runway centerline and centerline extended. The course may lie in two directions, forming both a front course and a back course, however, the back course localizer is the exception and should not be provided unless absolutely essential from an operational standpoint.

c. The localizer receiving equipment cross-pointer in the aircraft, responding to the differences in levels of detected 90- and 150-Hz signals, will be at the center of the meter when the two levels are equal, indicating aircraft alignment with the runway centerline. When the aircraft is to the right of centerline, the cross-pointer deflects to the left and when the aircraft is to the left of the centerline, the deflection is to the right. The angle in the front course sector which corresponds to full-scale deflection of the cross-pointer (the calibrated mark on the extreme left of the meter to that on the extreme right, or 150-0-150 microamperes) is defined as the course width. The localizer course width for the Category I ILS provides a breadth of 700 feet at the runway threshold, which in turn, provides a course width within the limits of 3 to 6 degrees. This setting provides almost uniform course sensitivity for all localizers independent of runway length. For Category II and III localizers, the course width is tailored for a breadth of 700 feet at the runway threshold and the course width shall not be greater than 6 degrees.

NOTE: Of course, where an offset localizer is used, the alignment and cross-pointer deflections are relative to the localizer alignment azimuth rather than the runway centerline.

d. The areas beyond the course width limits or the clearance signal sectors are defined (with respect to the localizer front or back course) as follows for the purpose of establishing minimum clearance requirements:

Sector	Defined Area	Minimum Clearance 1/
1	Course Edge to ±10°	160 µA
2	±10° to ±35°	135 µA
3	±35° to ±90°	135 µA 2/

1/ Minimum clearance values are for the broad-course width limit; add 15 μA to each reading to obtain minimum requirements for a normal course width.
2/ Ten miles throughout the sector between 35 and 90 degrees either side of the center of the course if adequate clearance is provided and a requirement exists for use of the facility in this area. Refer to the latest edition of Handbook OA P 8200.1, United States Standard Flight Inspection Manual for additional guidance on clearance requirements in Sector 3.

e. Ideally, the cross-pointer would remain fully deflected throughout the clearance sectors, precluding possible misleading needle deflections in these off-course areas. However, the unidirectional antenna arrays do not provide full clearances beyond ±35 degrees. Where a unidirectional array is used, compliance with the minimum requirements of Sector 3 are not necessary; however, an alternate navigational aid shall be available to provide guidance in this area.

f. It is also highly desirable for the localizer course to be a straight line which coincides with the runway centerline extended to permit maximum use of automatic approach equipment (see figure 2-1). In addition to increasing the difficulty of a manual approach, severe course aberrations such as roughness, scalloping, or bends may preclude the use of automatic approach equipment Departure of the actual localizer course from a theoretical straight line will, to some extent, determine the landing minimums. The permissible course displacement varies directly with the distance from runway threshold and is tabulated in Section 217 of Handbook OA P 8200.1.

NOTE: The airborne requirements in this handbook are based on information available at the time of publication. Handbook OA P 8200.1 continues to be the final source for current airborne performance requirements.

g. The principal cause of localizer course deviations and low clearance areas is the distortion of the antenna system radiation pattern by signal reflections or reradiation from nearby objects such as hangars, power lines, vehicular traffic, wire fences, and buildings (see figure 2-2). It may not be possible to remove these objects from the area; however, by judicious siting of the localizer antenna system, the effects of the degrading sources may in many cases be minimized.

h. The localizer usable coverage area, which is determined by a minimum received field strength of five microvolts, in addition to the minimum flag current and clearance signal requirements, is measured with the transmitter power reduced to the monitor alarm level. The minimum coverage requirements are : 18 nautical miles (nmi) within clearance sector 1; 10 nmi within clearance sector 2; and 10 nmi within clearance sector 3, if required by the approach procedure. The vertical coverage extends from the higher of the glide-slope intercept altitude or 500 feet above the highest intervening terrain to 4500 feet above the site elevation.

19. LOCALIZER LOCATION AND TYPES.

a. The ILS localizer consists of an antenna array, electronic equipment, integral detectors, and an equipment shelter. Category II and Category III localizer systems also include a far field monitor (FFM) which is sited near the inner or middle marker. The localizer is normally located near the end of the runway opposite the desired approach. However, the antenna array is the prime consideration and will, to a certain extent, fix the location of the building.

b. There are several types of FAA-procured localizer antenna systems in present use. The more familiar ones are: the V-ring array, the traveling wave antenna, and the log-periodic dipole antenna. The V-ring array is essentially bidirectional and was formally the FAA standard system, whereas the other types are unidirectional systems originally used to overcome V-ring siting problems caused by reflecting objects. The criteria contained in the following paragraphs apply generally to all systems. Any deviation from these criteria for the individual types of arrays are given in the succeeding paragraphs, which also provide a more thorough description of each system.

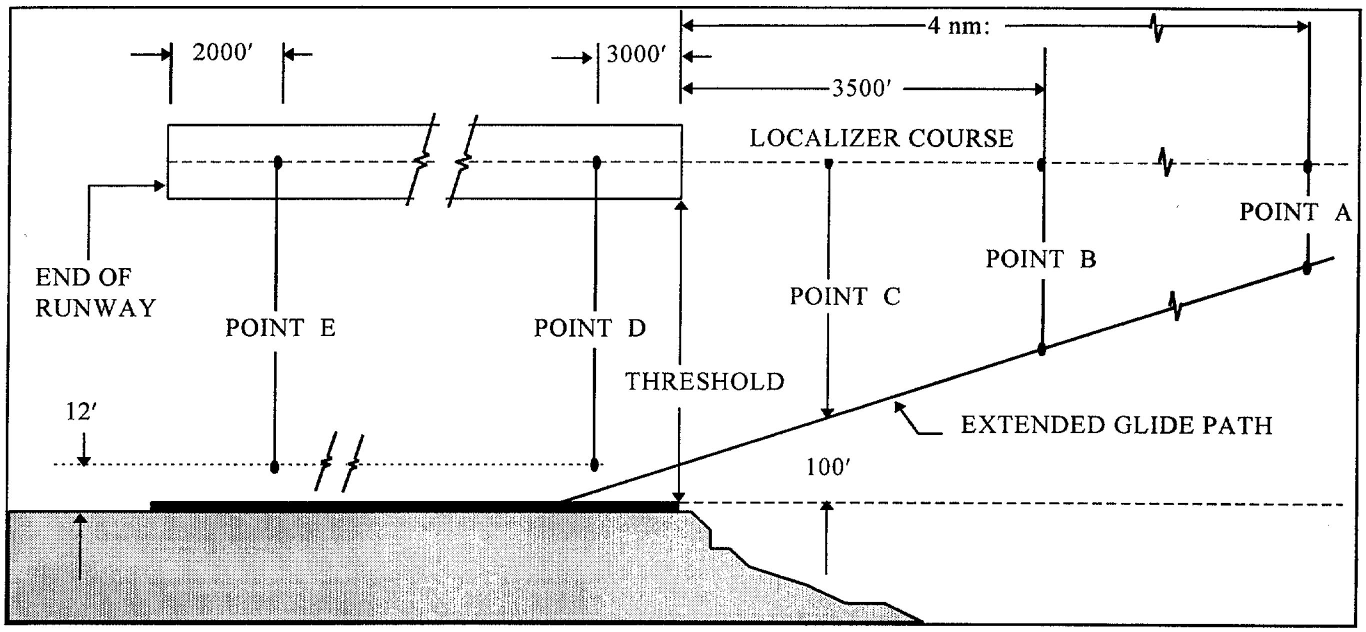


FIGURE 2-1. ILS COURSE DISPLACEMENT REFERENCE POINTS

Point A is located on the glide path 4 nautical miles outbound from the runway approach threshold, measured along the runway centerline extended (or the localizer approach azimuth).

Point B is located on the glide path 3500 feet outbound from the runway approach threshold, measured along the runway centerline extended (or the localizer approach azimuth).

Point C is located at the intercept of the downward-extended straight portion of the glide path (at the commissioned angle), the vertical plane containing the runway centerline extended (or the localizer approach azimuth), and the horizontal line 100 feet above the horizontal plane containing the runway threshold.

Point D is a point 12 feet above the runway centerline and 3000 feet from the threshold in the direction of the localizer.

Point E is a point 12 feet above the runway centerline and 2000 feet from the stop end of the runway in the direction of the threshold.

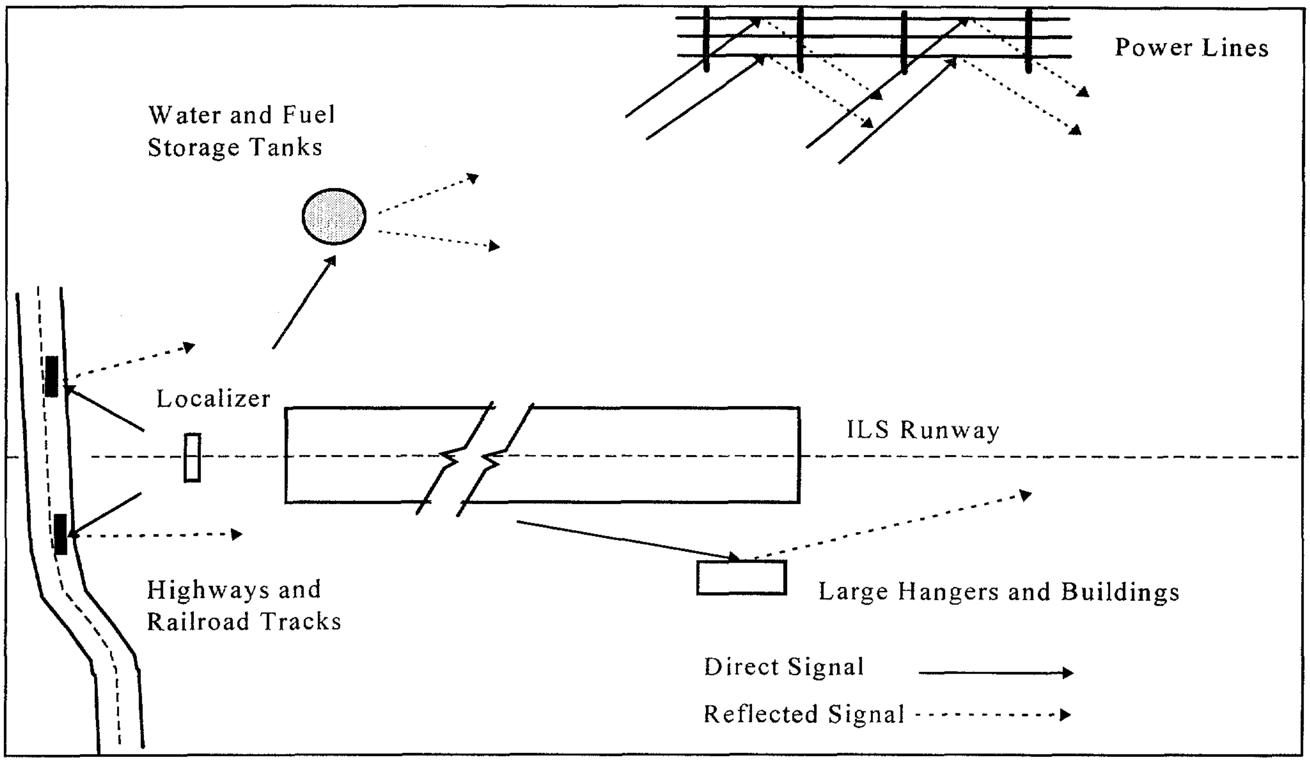


FIGURE 2-2. TYPICAL LOCALIZER DEGRADING SOURCES

20. SITING REQUIREMENTS.

a. The localizer antenna system shall be symmetrically positioned about the extended runway centerline (or localizer approach azimuth for offset configurations) with the longitudinal axis of the array perpendicular to the extended runway centerline (or approach azimuth). The optimum distance from the stop end of the runway to the localizer array for each site shall be determined by consideration of several factors:

(1) Required obstruction clearance criteria.

(2) Usable distance and signal coverage requirements.

(3) Presence of reflecting or reradiating objects in the vicinity.

(4) Safety considerations and the Runway Safety Area.

(5) Anticipated facility upgrading and/or airport expansion.

(6) Establishment costs.

b. Minimum antenna distance from the stop end of the runway to the localizer array shall be that distance which precludes penetration of the approach surface plane (FAR Part 77) and runway safety area by the localizer array. For centerline extended localizer antennas, the minimum distance from the stop end of the runway shall be the greater of 600 feet or the end of the runway safety area. Additional criteria pertaining to the minimum distance requirements are as follows:

(1) When a cleared and graded area extending from the stop end of the runway a distance of 1250 feet or more can be provided, the localizer shall be located beyond 1000 feet from the stop end of the runway.

(2) At joint-use airports, where a 1000-foot paved overrun area is required by military users, the localizer array shall be located beyond the 1000-foot paved overrun area.

(3) When site conditions preclude adherence to the FAR Part 77 approach surface plane, approval must be granted for violation of the approach surface plane in accordance with Subparts B and D of FAR Part 77. However, to assure protection from the effects of aircraft engine jet blasts, the minimum distance a localizer shall be located from the end of a runway where jet aircraft are in operation shall be the greater of 600 feet or the end of the runway safety area (RSA) of Advisory Circular, AC 150/5300-13, Airport Design. For Category II/III installations, refer to paragraph 24a of this Order for minimum distance requirements. An NCP to site the array between 600 and 450 feet from the end of the runway will be considered on a site to site basis. No consideration shall be given to siting the array closer than 450 feet from the end of the runway. Where siting conditions preclude adherence to the 450-foot limitation, consideration will be given to locating the array beyond the maximum distance limit or to an offset location.

c. The maximum standard distance from the stop end of the runway to the localizer array is 2000 feet. However, location of the array beyond this distance is permissible where significant advantages can be attained.

(1) When the localizer will serve a relatively short runway requiring a wide course width (5 to 6 degrees) to provide the 700-foot tailored width at threshold, the array may be located beyond the 2000-foot distance. When this type of siting condition is encountered, the maximum distance from the array to the approach threshold shall not exceed 13,370 feet for a category I localizer.

(2) Location of the localizer beyond the 2000-foot limit is permissible when airport expansion plans include a runway extension which would necessitate a future localizer relocation. Planned taxiway and building construction should also be considered in this regard.

d. The elevation of the array shall be considered in conjunction with the distance requirement. Although a ground-mounted array is usually adequate at most facilities, at some locations an elevated array may be necessary to provide the required minimum signal coverage. This may occur where the presence of hills, trees, buildings, or other obstructions in the vicinity causes a shadow effect. The array should be mounted so that the antenna radiating element is in line of sight with the threshold crossing height (TCH) at the approach end of the runway. All Category II/III sites must satisfy this criteria; however, at those locations where future upgrading to Category II/III is not programmed or considered feasible, i.e. runway length/width, annual instrument approaches, etc., the array may be mounted to provide optical line of sight to a point 100 feet over the threshold. This should be done after a complete site analysis has been completed that indicates satisfactory facility performance can be obtained with the lower antenna height. In the localizer frequency band, vhf propagation techniques may be used to find the usable distance for any given site and antenna height. The maximum height of the antenna element shall not exceed 35 feet above the immediate terrain.

e. The presence of signal-reflecting or reradiating objects in the vicinity may place an additional restriction on the location of the localizer antenna system. By application of the principles of specular reflection, the areas that will be affected by the reflected signals may be predicted by math modeling techniques available through the Washington ILS Program Office.

f. The quality of the front course and clearance areas is the primary consideration when establishing the localizer and shall not be compromised for the sole purpose of obtaining a usable back course approach. Expenditure of additional funds to upgrade the back course, even without degrading the front course, cannot generally be justified.

g. The terrain between the antennas and the end of the runway should not contain severe irregularities or obstructions that may affect the localizer signal quality. Existing obstructions should be removed and, if possible, the area graded. The V-ring array and unidirectional arrays require only minimum site preparation because of their directional characteristics. Terrain irregularities and isolated small objects close to the array will not usually affect the radiated signal quality. Clearing should be limited to the removal of large shadowing objects such as dense trees, shrubs, and hillocks from in front of the array and any significant signal reflectors in the vicinity of the array.

h. When a tentative antenna location, based on the signal coverage, obstruction criteria, and other requirements has been chosen for a localizer, the establishment costs shall be estimated. Items to be considered include the cost of installing power lines and control cable where required, the cost of site grading or landfill, the cost of the antenna support (concrete slab versus elevated platform), and the cost of constructing site access roads. The exact location of the array should be the least costly site consistent with the required level of service.

i. At some runways, terrain may prevent the localizer antennas from being positioned on the runway centerline extended. Where this occurs, and the cost of the landfill or a tall tower antenna support is prohibitive, the localizer antenna array may be offset so that the course does not lie along the runway centerline but rather intercepts the centerline at a point determined by the amount of angular offset and the glide path angle. The maximum localizer offset angle shall be 3.0 degrees. If the offset angle is greater than 3 degrees, the facility will be classified as a localizer directional aid (LDA). The localizer offset angle (see figure 2-4) is formed by the vertical plane containing both the decision height point (DHP) and the point on the runway centerline that is 1150 feet inbound from the DHP (with the latter place also containing the localizer course line). The landing minimum of an ILS or an LDA is contained in Federal, Aviation,Administration Handbook 8260.3A.United States Standard For Terminal Instrument Procedures (TERPS). The criteria for standard localizer facilities shall apply also to an offset localizer with the following exceptions or amendments.

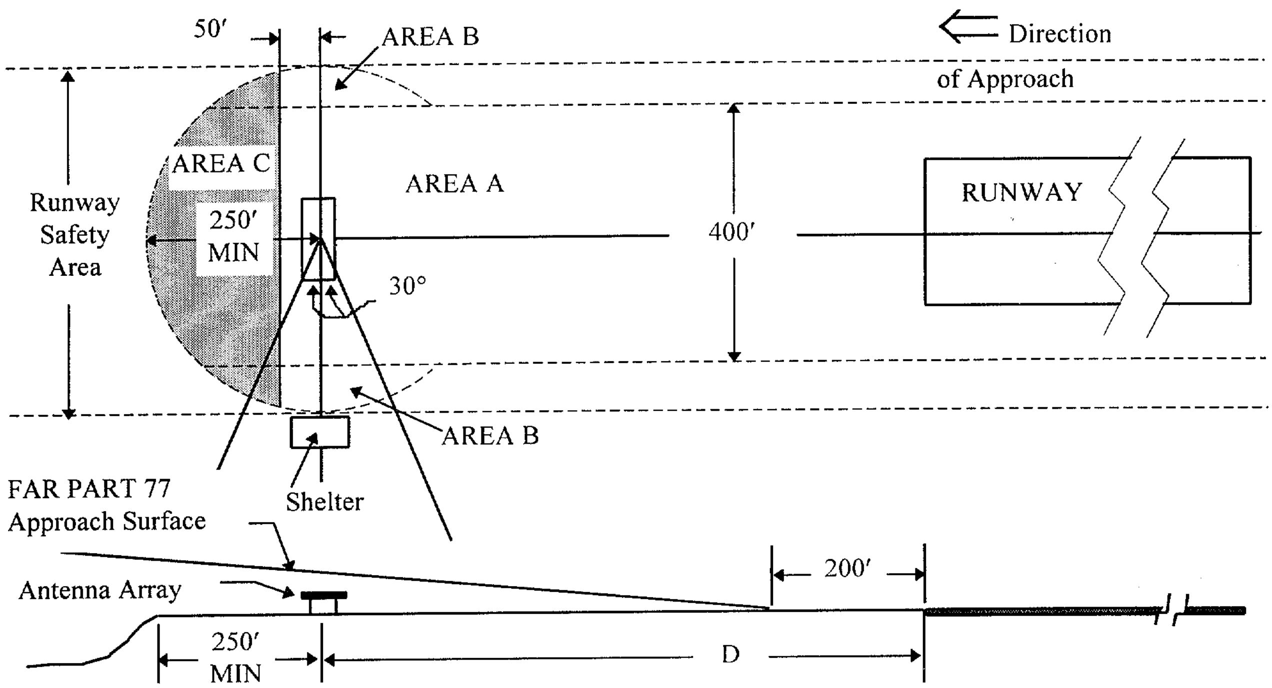
(1) The antenna array should be offset in the direction that will offer the least signal interference from movement or obstructions. The distance from the array to the approach threshold shall be the maximum distance consistent with satisfactory engineering analysis and site conditions but shall not exceed the perpendicular extension of the 2000-foot distance limit from the stop end of the runway that applies to normal localizer configurations.

(2) An offset localizer must comply with the minimum distance of the array from the stop end of the runway and from the runway centerline established by airport geometric constraints and ILS runway obstruction criteria.

(3) The distance from the runway centerline to the nearest element of the array shall comply with the obstacle free zone (OFZ) criteria of AC 150/5300-13, Airport Design. (See figure 3-11.)

(4) No portion of the array shall be located within the applicable taxiway safety area as defined in AC 150/5300-13, Airport Design.

(5) The antenna array shall be sited to provide vertical and horizontal clearance to taxiing aircraft on adjacent taxiways.



NOTES:

1. Areas A and B should be free of localizer interference sources (trees, buildings, fences, etc.)
2. Grading may be limited to removal of interference sources in Areas A and B.
3. The size and configuration of Areas A and B are applicable to all facilities except that Area C (shaded area containing portions of Areas A and B) may be deleted at facilities that have unidirectional antennas; i.e., Log Periodic Dipole arrays.
4. Distance D, determined by terrain and siting conditions, with minimum distance limited by the localizer antenna array and transmitter shelter's compliance with obstruction clearance criteria. The antenna should be located beyond 1000 feet from the stop end of the runway.
5. Transmitter shelter shall be located at a minimum distance of 250 feet from the runway centerline and centerline extended. The transmitter shelter should be located within ±30 degrees of the antenna's longitudinal axis.

FIGURE 2-3 TYPICAL LOCALIZER PLOT LAYOUT AND SITE GRADING REQUIREMENTS

(6) The criteria for location of the equipment shelter are:

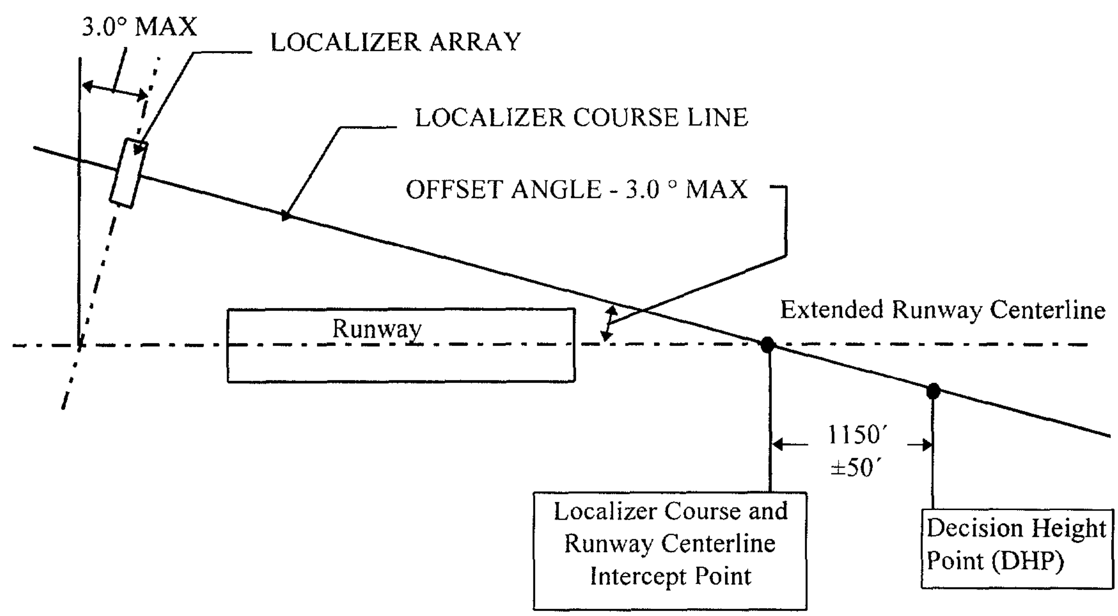
(a) The shelter shall not be located between any portion of the permissible antenna location and the runway.

(b) The shelter shall not be located within 250 feet of the extended runway centerline.

(c) The shelter may be located within 100 feet of the array center on the extended back course line or within ±30 degrees of the longitudinal axis (array on side away from runway) of the array except as restricted in paragraph 8.

(d) If an elevated array is installed, the shelter may be located directly behind the platform, provided the elevation of the top of the shelter does not exceed the level of the platform and as restricted in para. 3.

j. To obtain optimum performance from the localizer, all of the above factors must be considered when siting the antenna system and determining the type of mounting structure. If the engineering survey indicates that the required obstruction clearance or other criteria cannot be followed, an NCP shall be submitted and approved prior to the commencement of construction.



NOTES:

1. See TERPS handbook for the lowest permissible landing minimums for a full ILS with an offset localizer.

2. Markers shall be established in accordance with current criteria using the localizer course line rather than the extended runway centerline as the reference line.

FIGURE 2-4. OFFSET LOCALIZER CONFIGURATION

21. LOCALIZER EQUIPMENT SHELTER.

a. The electronic equipment shelter shall be located a minimum distance of 250 feet from the center of the runway and should be within ±30 degrees of the longitudinal axis of the array. When a V-ring antenna system is used, it is preferable, to locate the shelter in the minimum signal area that exists at 105 degrees from the front course line and at the above distances. The maximum distance to the building is limited by the attenuation of the antenna feedlines. Use of low-loss foamed dielectric cables permits the building to be located as much as 500 feet from the antennas. The building may be situated on either side of the antennas depending on the local terrain, access roads, and powerline connections.

b. The size and type of existing ILS equipment shelters is dependent on the time frame in which the original ILS was established. Some contracts provided for the use of enclosed portable shelters of various sizes to house the equipment. Current ILS equipment contracts do not include shelters. Future shelter requirements will be satisfied through Regional procurement action. Transportable shelters are easily moved and cost less than the permanent buildings and they are recommended for all new installations. The criteria for location of the shelter shall apply to both permanent buildings and portable shelters.

22. DESCRIPTION OF THE ANTENNA SYSTEMS.

a. The V-ring Array.

(1) The V-ring localizer array is a bi-directional self-clearing antenna system. It provides front and back course information using a single set of transmitting equipment.

(2) The directional radiation pattern of the V-ring array is obtained from a system of eight or 14 antennas symmetrically arranged to form either a 45.5 or 85.8-foot aperture respectively. The electrical spacing of the antennas and the ratio of the rf power distributed to the antenna determine the characteristics of the radiation pattern; these two parameters are designed to provide a very high pattern intensity along the course line and a much lower field strength sufficient to provide adequate clearances in the off-course areas. In addition, a front-to- back pattern ratio of about 2.5:1 is obtained from the directive characteristics of the individual V-ring antennas.

(3) Site preparation for the V-ring includes minimum grading, as previously noted, and construction of the antenna array mounting support. The mounting support will be a concrete slab for a ground-mounted system or a wooden platform where antenna elevation is required. Bolts for mounting the array assembly are installed in the correct positions on the structure. The structure is 50 feet long by 4 feet wide (8 element array) or 90 feet long by 4 feet wide (14 element array) with the long axis perpendicular to and bisected by the runway centerline extended.

b. Unidirectional antenna array. The unidirectional antenna array, is the log-periodic dipole antenna array (LPD). This array incorporates integral monitoring, and is designed to provide coverage to ±35 degrees on the front course. The LPD array is furnished in two versions, an eight-element antenna array (narrow-aperture array) and a fourteen-element antenna array (wide-aperture array). These arrays are approximately the same physical size as a corresponding V-ring array. The front-to-back radiation ratio of these arrays is at least 23 dB. The carrier pattern beamwidth is 22 degrees for the narrow-aperture antenna array and 9 degrees for the wide-aperture antenna array at the half-power point.

c. The Wilcox Mark II system consists of 14 LPD antennas that are fed two frequencies through a capture effect radio frequency distribution network. The difference in frequency is normally 9.5 kHz.

d. The Wilcox Mark III (Category III) system consists of 14 LPD antennas (approximately 105 feet wide), that are fed two frequencies through a capture effect radio frequency distribution network. The difference in frequency is normally 8 kHz.

23. GROUND CHECK POINTS (refer to figure 2-5).

To facilitate the establishment of the facility parameters and to provide reference points from which the parameters can be periodically verified, ground checkpoints shall be established at each localizer facility. Because of the different types of localizer arrays and the unique terrain and siting conditions at each facility, it is not possible to specify the exact location and number of checkpoints. As a minimum, the following ground checkpoints shall be determined by survey and permanently marked.

a. Course line in the far field (beyond 3000 feet for wide-aperture arrays) preferably at or near the approach threshold.

b. Course edges 0.155 difference in depth of modulation (DDM) points in the far field preferably at or near the approach threshold, but not less than a distance equal to 20 times the width of the antenna array.

c. Quadrature phasing location in the far field.

(1) The distance between the antenna array and the quadrature ground checkpoints shall be a minimum of twenty times the antenna aperture.

d. Clearance signal checkpoints.

(1) All antenna arrays: For all antenna arrays (single and dual frequency), only two ground checkpoints, one on each side of the course, need be established. These two points shall be at the low clearance DDM points established at the theoretical low clearance point of the specific antenna array and shall be within ±35 degrees of centerline but outside the localizer course. The two points shall be located at the approach end of the runway or along the line of sight towards the antenna array where adequate signal strength and reliable readings can be obtained. The distance between the antenna array and the clearance ground checkpoints shall be a minimum of twenty times the antenna aperture.

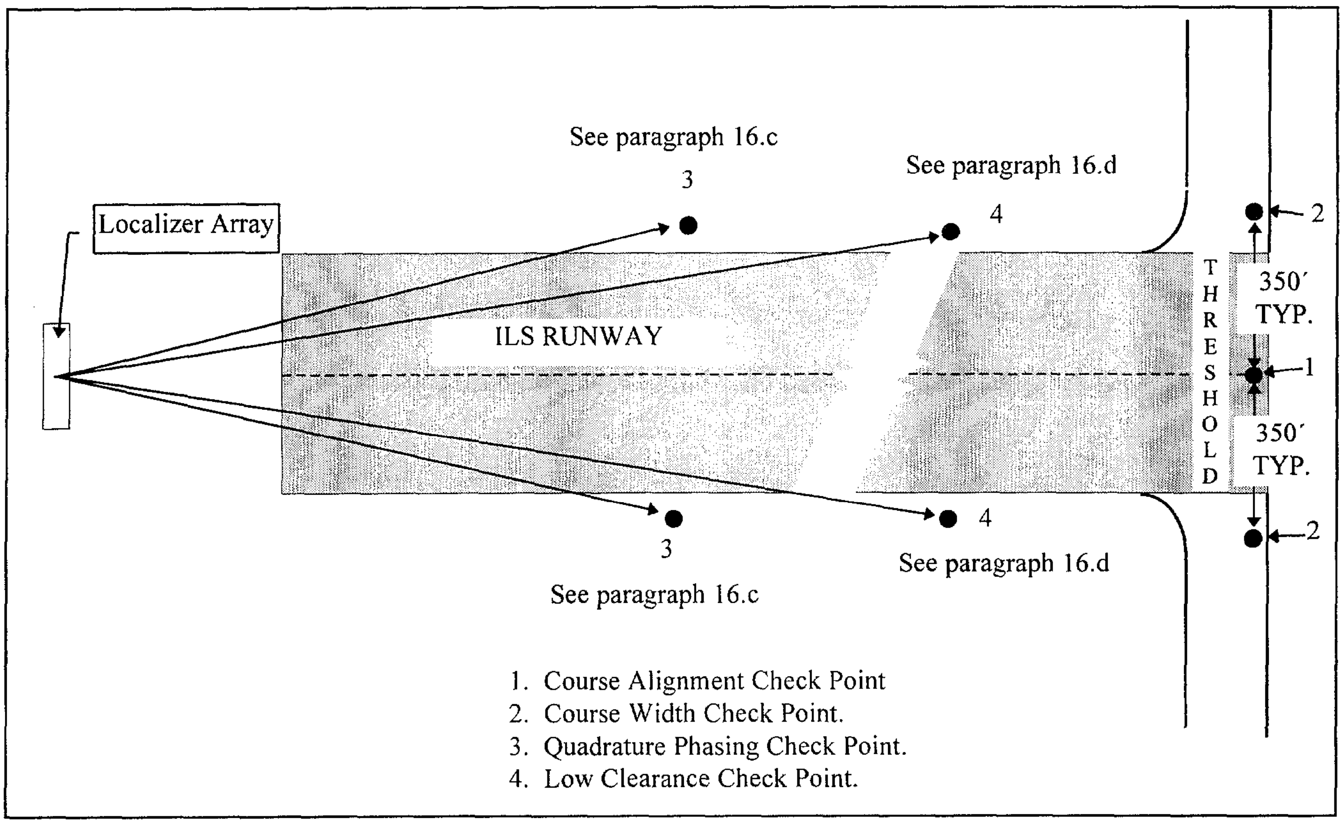


FIGURE 2-5. LOCALIZER GROUND CHECK POINTS

24. SITE EFFECTS ON LOCALIZER PERFORMANCE.

a. When planning a localizer, the effect of the particular siting conditions on the antenna array's radiation pattern shall be studied. A thorough analysis will help determine the optimum antenna location within the defined limits and will permit an accurate prediction of the system's performance at a particular site. If it is not possible to make an accurate prediction of the systems expected performance from the information available, a request for mathematical modeling assistance should be submitted in accordance with paragraph 2 of Appendix 2.

b. Although future localizer establishments will probably use LPD systems, comparison of the radiation patterns of the various systems should be made when planning relocation, modernization, or a performance upgrade on existing systems. The LPD system will generally be used to provide improved performance over a 15 element V-ring array. When relocation of a 15 element V-ring array is required, simultaneous conversion to an eight or 14 element V-ring or LPD is recommended. If a back course is not required, conversion to an eight or 14 element LPD is preferred.

c. When evaluating a site prone to signal reflections, the effect of the reflected signal on both the course structure and on the clearance signals, particularly in sector 1, (see paragraph 11d herein) shall be considered. The reflected signal will add vectorially to the direct signal in these areas, resulting in a corresponding deterioration in the quality of the guidance information.

(1) The directive characteristics of the V-ring, and the LPD arrays provide a high direct-to-reflected signal ratio in the course sector area reducing the effects of off-course reflections on the course structure. Improvement in the direct-to-reflected signal ratio at sites affected by reflections originating beyond ±10 degrees is obtained from a capture effect LPD antenna array.

(2) Low clearance areas (below 150 µA) usually are caused by the reflection of signals from one side of the radiation pattern into the opposite side (i.e., 90-Hz signal reflected into the 150-Hz sectors or vice versa), the extent of the clearance signal reduction varying inversely with the ratio of direct-to-reflected signal amplitude. Reflection problems may be resolved by selection of the optimum location of the antenna array and by altering or removing the reflection source. It is imperative that adequate clearances be obtained in sector 1; full scale clearances in sectors 2 and 3 are also desirable but not mandatory if an additional navigational aid is available to guide the aircraft into the usable sectors.

25. CATEGORY II AND III RUNWAYS.

The following siting requirements for Category II and Category III localizer arrays should be considered when planning an ILS establishment at locations where future upgrading to category II or Category III operation is anticipated.

a. Optimum distance from the stop end of the runway to the array should be beyond 1000 feet. The minimum distance from the stop end of the runway to the array shall be not less than 600 feet or the end of the runway safety area, whichever is greater.

b. Compliance with obstruction clearance criteria to assure maximum compliance with category II and category III requirements is required. Refer to the latest edition of FAA Order 8260.3, (TERPS).

c. Category II/III localizers shall only be located on the runway centerline extended.

26. RESERVED

CHAPTER 3. THE ILS GLIDE SLOPE

27. GENERAL DESCRIPTION.

a. ILS glide slopes operate in the frequency band of 329.15 through 335.0 MHz, with 40 discrete frequencies available within this band. Each glide slope frequency is paired with a given localizer frequency, forming one ILS channel. The glide slope's guidance information is also provided by 90- and 150-Hz modulation components. Identification signals are not provided with the glide slope.

b. The glide slope antenna system is located on a line parallel to the runway centerline, and at a distance outside the OFZ as determined from figure 3-11. The end-fire glide slope antenna system, however, is located close to the runway centerline. The exact antenna location on this line with respect to the point on the line that is directly abeam of the runway threshold depends upon operational conditions.

c. The glide slope site may be located on either side of the runway. The most reliable operation will occur when it is located on the side that provides the least interference from buildings, power lines, moving vehicles, and aircraft and which has the greatest extent of smooth terrain outbound from the antennas. Category II and Category III glide slopes should be located at a minimum of 400 feet from the runway centerline.

28. OPERATIONAL DESCRIPTION.

a. Proper operation of the glide slope is primarily a function of the quality of the vertical radiation lobe structure. The system is designed so the radiation structure has a predominance of 150-Hz signal below the glide path and, conversely, a greater level of 90-Hz signal above path. The glide path itself is the loci of the points where equal levels of 90- and 150-Hz signals exist. The elevation angle of the glide path is a function of the antennas' heights above ground in the image systems. For the end-fire system, the relative phase of the rf radiation from the rear and front course antennas, determines the glide path angle.

b. The aircraft glide slope receiver responds to the difference in detected levels of the 90- and 150-Hz signals. When the aircraft is on the glide path, the glide path cross-pointer receives equal levels of 90- and 150-Hz signals and remains at mid-scale; the cross-pointer deflects downward when the aircraft is above path (90 Hz predominate) and upward when below path (150 Hz predominate) indicating "fly-down" and "fly-up," respectively. The vertical arc corresponding to full-scale deflection of the cross-pointer (150-0-150 μA on a calibrated receiver) is defined as the glide path sector width.

c. It is desirable that the glide path be a smooth line approaching a theoretical hyperbolic curve. In the area above and below the path sector width (the clearance signal area), the differences in the detected 90- and 150-Hz signals shall be sufficient to maintain the cross-pointer in a fully deflected position. The latter is of particular importance in the below-path areas. The usable distance of the glide slope shall be 10 nautical miles, with a horizontal coverage of 8 degrees on each side of the localizer on-course (or procedural designed azimuth).

d. The maximum permissible displacement of the glide path due to bends, scalloping, or roughness in Category I, II, and III operations is tabulated in Section 217 of FAA Handbook OA P 8200.1.

e. The ability of the glide slope to meet the operational requirements depends to a great extent on the terrain conditions between the antenna system and the receiving aircraft and the absence of objects which may reflect or re-radiate undesirable energy into the glide path area.

29. TERRAIN CONSIDERATIONS FOR IMAGE-TYPE GLIDE SLOPES.

a. The glide slope depends on the terrain conditions due to the inherent image antenna concept: radiation from an antenna located above a reflecting surface (the ground terrain in the case of the glide slope) travels two different paths to the receiving antenna, a direct path and an indirect path via the reflecting surface. The reflected signal appears to emanate from an "image" antenna along the same vertical plane as the real antenna and at a distance below the reflecting surface equal to the distance of the real antenna above the surface (see figure 3-1). The signals from the real and image antenna combine vectorially in space. Therefore, the three types of glide slopes are often referred to as "image" systems. The glide path information (null reference system) is formed by the vector sum of four different signals: the direct and reflected signals from the carrier antenna and the direct and reflected signals from the sideband antenna.

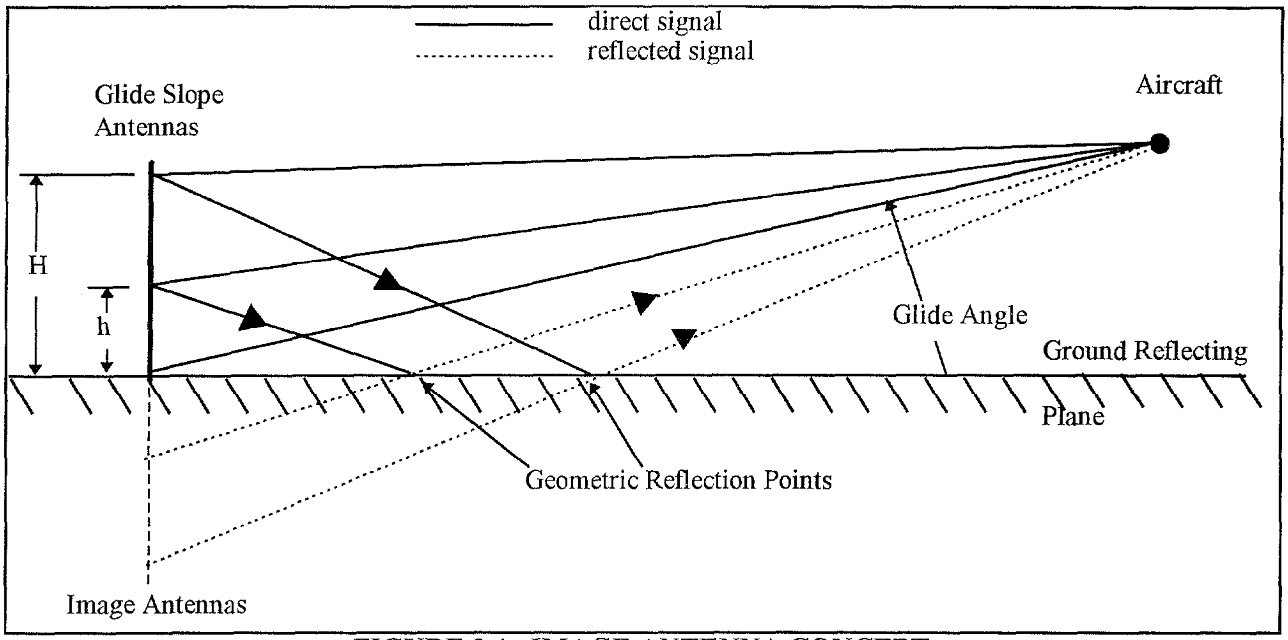


FIGURE 3-1. IMAGE ANTENNA CONCEPT

b. Although figure 3-1 indicates a single point of reflected energy, reflection actually occurs from the entire area which is specularly illuminated by the antenna. The area of reflection consists of a number of concentric zones called Fresnel zones (see Appendix 3) which are numbered outward. The extent of each Fresnel zone is determined by the phase lag of the reflected signal from that zone. The phase lag is a function of the differential path length between the direct and reflected signals, with the phase from each zone lagging that from the next inner zone by pi radians or 180 degrees. Signals from the second and succeeding zones, being of approximately the same amplitude but opposite in phase, cancel almost completely. Therefore, when siting the glide slope only the first Fresnel zone normally need be considered.

c. The size and position of the glide slope Fresnel zone is a function of the glide path angle and the aircraft's elevation and distance from the facility. When the aircraft is over the outer marker, the Fresnel zone appears as a long narrow ellipse. As the aircraft approaches the runway, the ellipse becomes continuously smaller and gradually rotates as depicted in figure 3-2. The distance to the geometric ground reflection point and the distance to the Fresnel zone center are plotted in figures 3-3 and 3-4 respectively for various glide path angles. The length and width of the

Fresnel zone are plotted in figures 3-5 and 3-6 respectively. These graphs are for the sideband (upper) antenna, for a null reference system, and for ideal reflecting terrain.

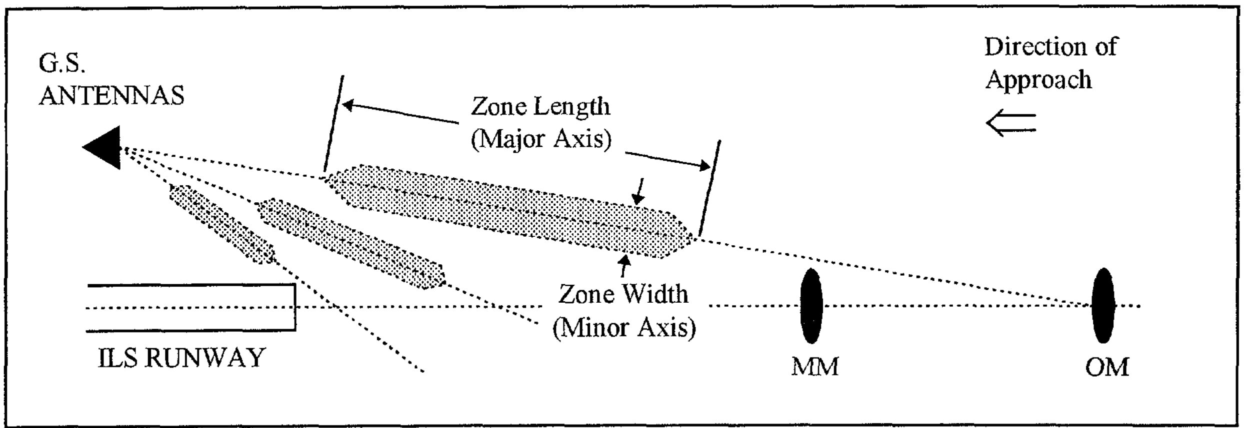


FIGURE 3-2. FIRST FRESNEL ZONES FOR ILS GLIDE SLOPE

d. The quality of the glide slope information, the smoothness of the glide path, the linearity of the normal approach envelope transitions, and the adequacy of the off-path clearances are, a function of the Fresnel zone terrain conditions. Where the terrain encompassing all of the Fresnel zone is level and uniform, the glide slope signals will approach the theoretical values; where the terrain is irregular or nonuniform, the glide slope will deteriorate accordingly. It is necessary, therefore, to determine whether the terrain's departure from the perfect ground plane can still provide a satisfactory glide slope facility.

e. Items to consider when determining the extent of departure of the glide slope terrain from a perfect ground plane include the consistency of the terrain and its coefficient of reflection, the terrain slope or departure of the terrain from the horizontal plane, and the magnitude and extent of broken or irregular terrain or terrain roughness.

(1) For the horizontally polarized glide slope radiation and the low grazing angle of the ground-reflected, far-field signal, the ground plane coefficient of reflection has a range of 0.94 for dry, sandy soil to 1.0 for sea water. Therefore, if the Fresnel zone surface is smooth and constant, the coefficient of reflection can be assumed to equal one (R= 1) without introducing significant error. Where the Fresnel zone is smooth but not consistent, as where the approach path is partially over water, a sudden change may be encountered in the received signal as the coefficient of reflection changes instantaneously. This effect is unavoidable; however, it can be minimized by establishing the lowest possible glide angle (and, therefore, the lowest possible grazing angle) and/or locating the glide slope antennas, within the specified criteria, so that the change in the received signal does not occur within a critical part of the approach.

(a) Two additional problems encountered with above water approaches are the vertical shift in the plane of the Fresnel zone resulting from tides and the dispersion of the ground plane signal by high waves or choppy water. Where these conditions are encountered, the antennas should be located to take advantage of the greatest amount of soil reflection, and possible use of a sideband reference or end-fire system may be required.

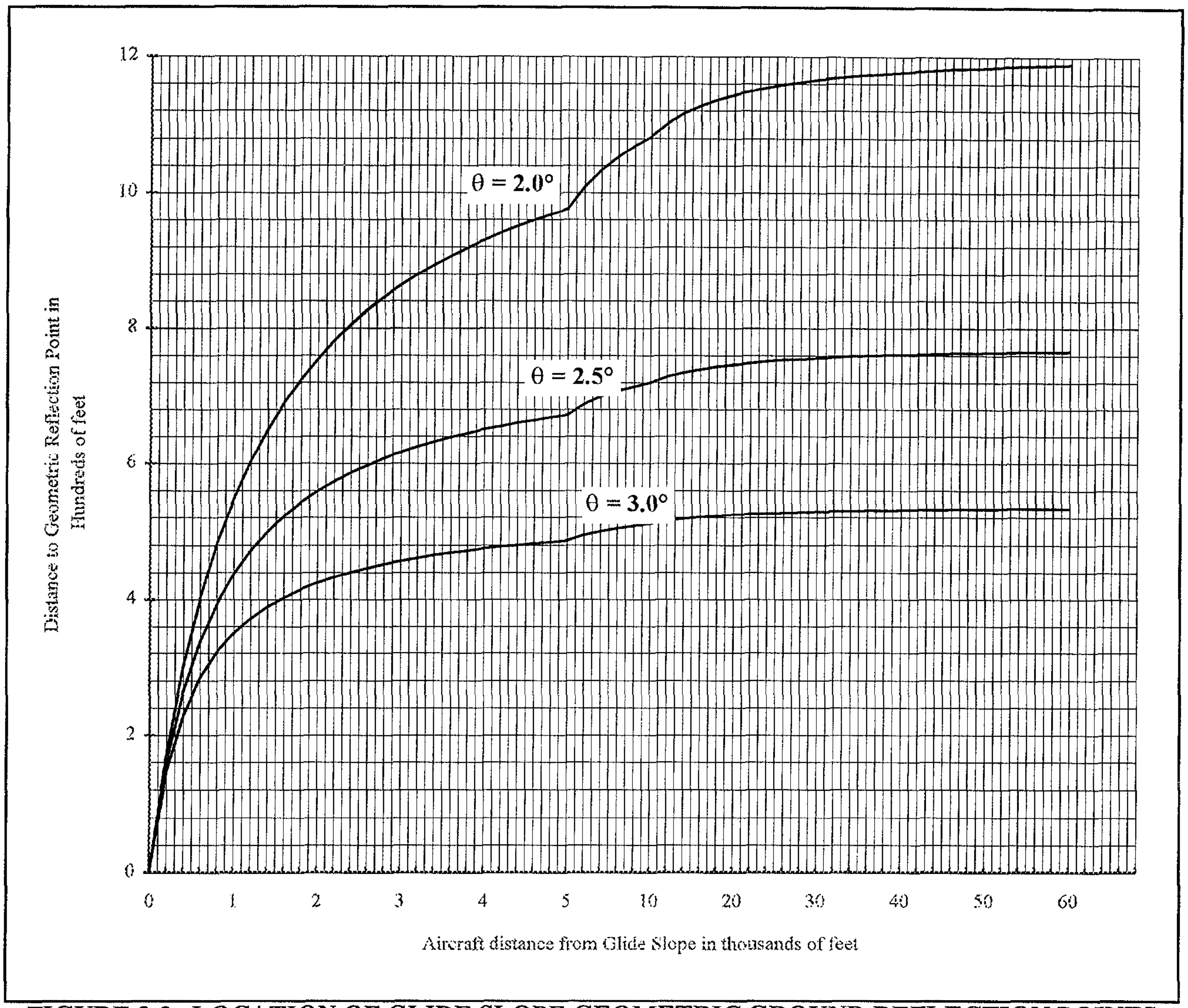


FIGURE 3-3. LOCATION OF GLIDE SLOPE GEOMETRIC GROUND REFLECTION POINTS

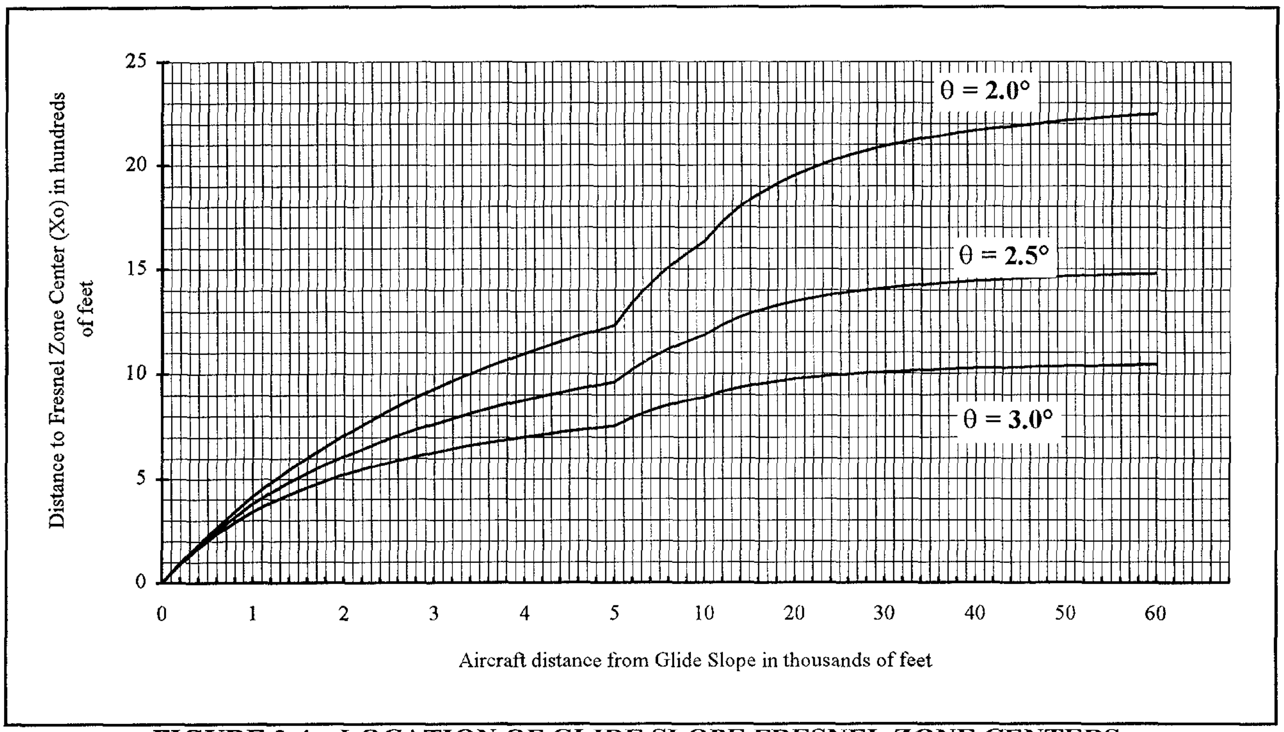


FIGURE 3-4. LOCATION OF GLIDE SLOPE FRESNEL ZONE CENTERS

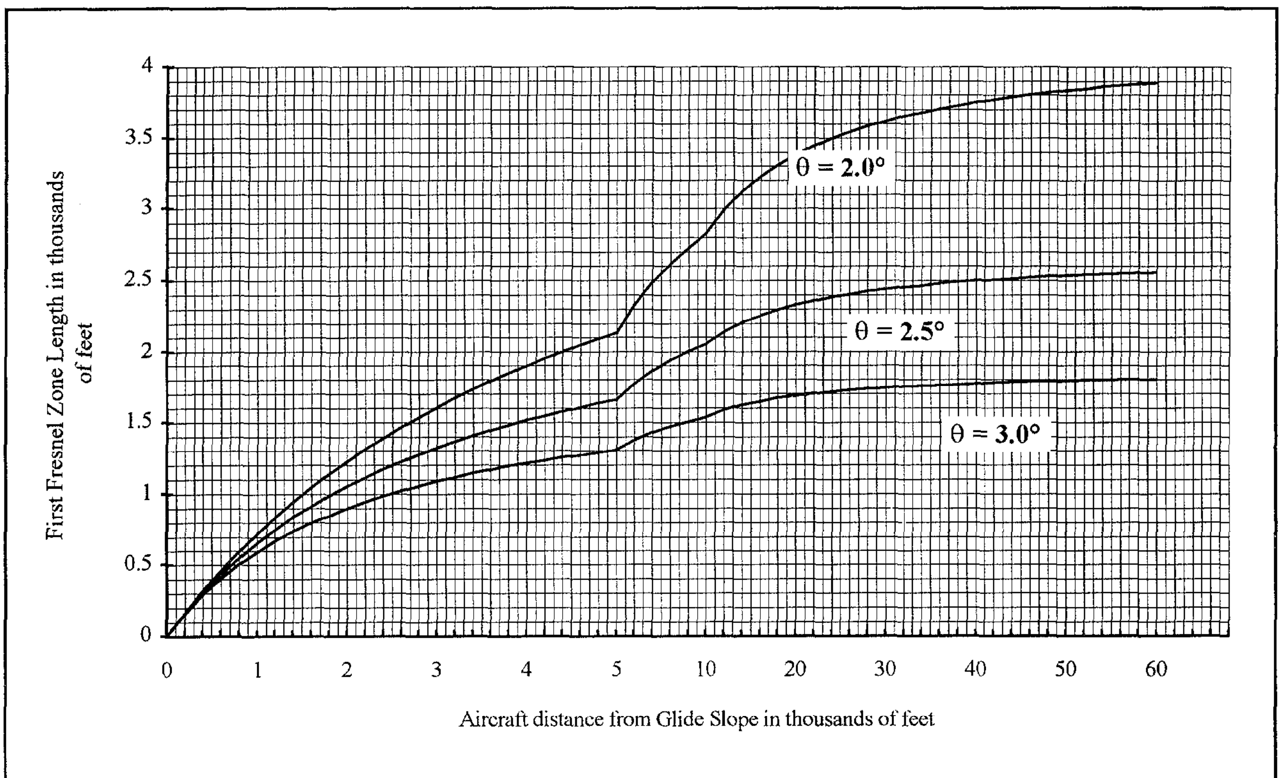


FIGURE 3-5. FIRST FRESNEL ZONE LENGTH AS FUNCTION OF GLIDE ANGLE AND AIRCRAFT DISTANCE FROM GLIDE SLOPE

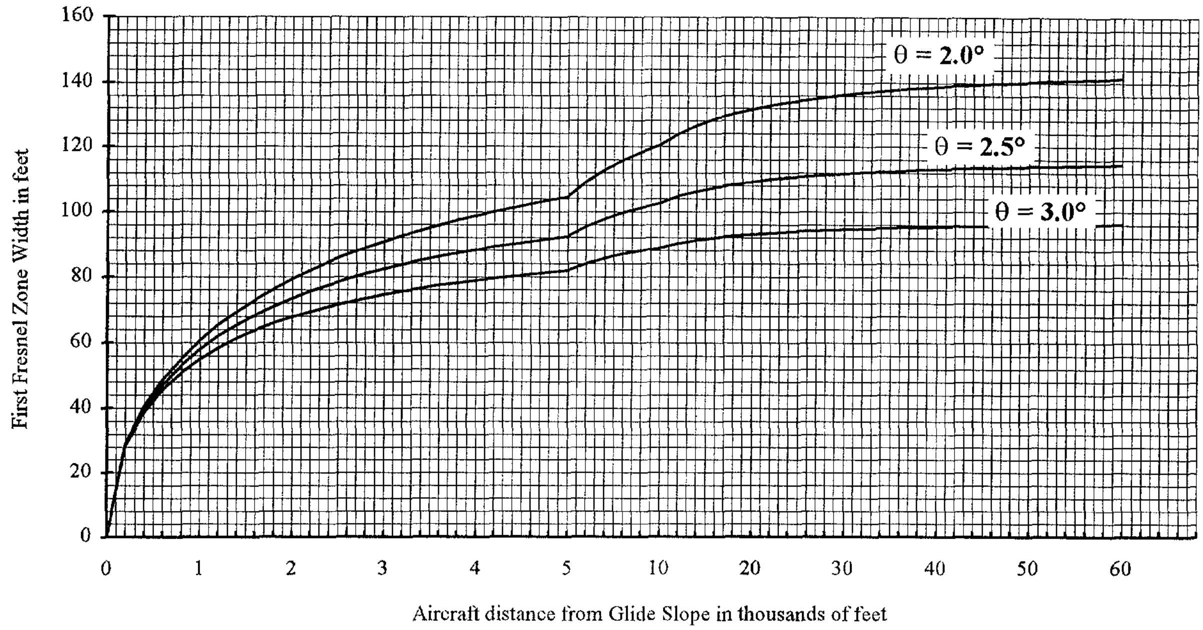


FIGURE 3-6. FIRST FRESNEL ZONE WIDTH AS FUNCTION OF GLIDE ANGLE AND AIRCRAFT DISTANCE FROM GLIDE SLOPE

(2) The theoretically evolved glide slope assumes that the ground surface lies in the horizontal plane. In practice, this is seldom the case, because the terrain at and in the vicinity of most airports generally has some slope. As a result, the radiation patterns will be rotated either up or down relative to the horizontal plane through the base of the antenna mast in the same direction and by the same amount as the terrain slope. With the slope at a constant rate, the effect is overcome by adjustment of the glide angle in a direction opposite to and by the same amount as the slope angle (refer to paragraph 33g).

(3) Terrain irregularity or roughness is the worst and most common glide slope siting deficiency. The degrading effect of rough terrain results from the random dispersion and/or phase shift of the ground plane signal, which precludes formation of the desired glide slope pattern. Since it is obviously not feasible to provide a smooth ground plane for the entire glide slope Fresnel surface, it is necessary to establish a terrain roughness that can be tolerated.

(a) Criterion for Roughness. Terrain is considered to be rough if the phase shift in the ground-reflected signal caused by the change in the average path length would result in an out-of-tolerance glide slope. By application of Rayleigh's roughness criteria to the glide slope (see appendix 3), the limitation of terrain irregularities is:

$$Z \leq (.0117)\frac{T}{H}$$

where: Z = height of irregularity (in feet)

T = distance from glide slope antenna to irregularity (in feet)

H = height of sideband antenna in wavelengths

Hence, irregular terrain roughness is a function of both the distance to the irregularity and the antenna height or glide angle. For a 2.5-degree glide angle, terrain irregularities exceeding 1 foot per 1000 feet from the antennas would be considered as roughness: for a 3.0-degree glide angle, the limit on terrain variations would be 1 .22 feet per 1000 feet.

(b) Extent of Terrain Roughness. Because the terrain reflects the ground signal in a specular manner, slight departures from the smooth terrain for small distances (about 10 feet or less) will not usually have an adverse effect on the glide slope signal. The smooth terrain terminates when it encounters extensive roughness or singular roughness of a large magnitude such as a wide ditch, a hill, or valley. The reflected signal contribution must be continuous for the terrain to be considered smooth; therefore, the smooth surface terminates at the point where roughness is encountered even though a smooth reflecting surface exists beyond the roughness. Contributions from the latter surface must be considered a second order effect.

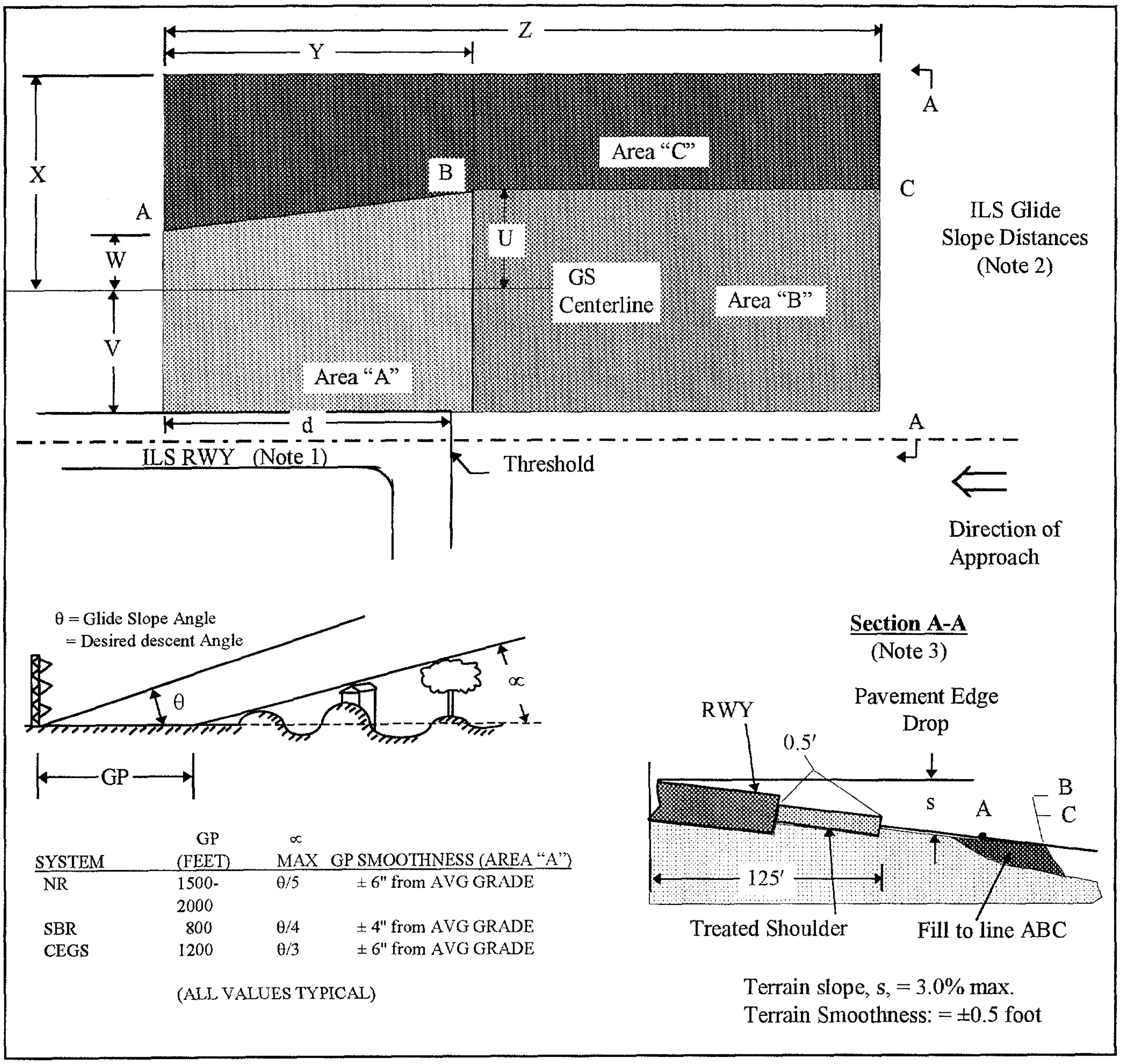
30. SITE PREPARATION. Although it would be desirable to provide an ideal operating environment for each glide slope facility, at most locations it would be physically or financially unfeasible to do so. Consequently, the site preparation requirements are less than ideal and represent a compromise between theoretical and practical requirements. When preparing a given site, several factors must be considered:

a. Grading criteria. As indicated by figures 3-3, 3-4, 3-5, and 3-6, the first Fresnel zone extends from the antennas outward for up to 3000 feet and up to 130 feet wide. It would be desirable to grade the entire area encompassing the Fresnel zones to provide a smooth ground plane. In accordance with the roughness criteria and economic feasibility, this should be done. However, at most locations the Fresnel zone extends beyond the airport boundaries; this limits the terrain that can be graded. A site conforming to the minimum grading criteria, as depicted in figure 3-7 and 3-7a, will generally provide a satisfactory glide slope if the terrain beyond the specified limits does not contain severe irregularities or interference sources.

b. Severe terrain discontinuities which would require extensive and unfeasible landfill or cutting operations to provide the required smooth terrain limit the use of the null-reference glide slope. Where this type of siting condition is encountered, the use of an alternate image type glide slope or end-fire glide slope shall be considered during the site analysis. Where the smooth terrain extends for a distance of less than 2000 feet, a sideband reference system may provide satisfactory operation; if terrain roughness is severe throughout the Fresnel zone area, a capture effect or end fire glide slope should be considered. If site preparation costs required for an image glide slope system to satisfy the grading criteria shown in Figure 3-7 are estimated to equal or exceed $300,000, an end-fire glide slope antenna shall be programmed for installation. This requirement is dependent upon a site which is acceptable for cenventional end fire antenna system operation with respect to the slope of the far field; refer to paragraph 32a of this order.

c. The presence of signal interference sources (such as power lines, fences, buildings, and other metallic structures) which may reflect or re-radiate the glide slope signal into the usable sector should be considered during the site analysis. When feasible, all such objects should be removed, particularly those in the approach zone. If removal is impossible and the interference source is sufficiently low, a capture effect system will partially overcome the effects of the low-angle reflections.

d. The glide slope may be located on either side of the runway. Therefore, all other siting factors (terrain, accessibility, etc.) being equal, the glide slope should be located on that side of the runway which is free of taxiways, runways, helicopter pads, and other potential sources of traffic interference. To preclude relocations necessitated by new construction, future airport expansion plans should also be considered when determining the site selection.



SYSTEM	GP (FEET)	∝ MAX	GP SMOOTHNESS (AREA "A")
NR	1500-2000	θ/5	± 6" from AVG GRADE
SBR	800	θ/4	± 4" from AVG GRADE
CEGS	1200	θ/3	± 6" from AVG GRADE

FIGURE 3-7 GRADING CRITERIA FOR IMAGE-TYPE ILS GLIDE SLOPES (sheet 1 of 2)

e. If the siting conditions offer no satisfactory alternatives, exclusion of the glide slope and the establishment of a partial ILS should be considered. The partial ILS consisting of a localizer and outer marker may provide sufficient improvement in the landing minimums or in the safety factor to justify omission of the vertical guidance information provided by the glide slope.

NOTES:

1. Locate glide slope on runway side away from taxiways, roads, etc.

2. Distances:

   d - determined by operational requirements and terrain conditions.
   U - 200 feet.
   V - 250 feet to 650 feet.
   W - 100 feet.
   X - 400 feet.
   Y - The greater of 1200 feet or the distance "d".
   Z - The least of : (a) 3000 feet; (b) distance to the airport property line; (c) distance to where smooth terrain terminates.

3. Grading and obstruction removal:

   a. Area A shall be uniformly graded (per figure 3-7) and should have the same longitudinal slope as the runway.

   b. Area B should be smooth-graded to comply with terrain roughness criterion of paragraph 29.e(3)(a). Extensive landfill operations determined by feasibility.

   c. Area C grading may be limited to removal of hills which would reflect the glide slope signal into the usable area.

   d. All possible interference sources (metallic structures, fences, etc.) should be removed from areas A,B, and that portion of Area C that is within 250 feet of the antenna centerline extended.(Refer to paragraph 30c.)

FIGURE 3-7a GRADING CRITERIA FOR IMAGE-TYPE GLIDE SLOPES (sheet 2 of 2)

31. PHYSICAL PLANT REQUIREMENTS.

a. The physical plant required for the glide slope consists of the antenna mast, equipment shelter, and the interconnecting cables. The glide slope mast heights may vary from 25 feet for a sideband reference to 50 feet or higher for a capture effect system. The top of the mast excluding the obstruction light shall be less than 5 feet above the center of the upper antenna.

NOTE: The mast heights listed above are for a glide slope angle of 3.0 degrees. If a glide slope beyond these limits is required, refer to Order 6750.54, Electronic Installation Instructions for Instrument Landing System (ILS) Facilities, and paragraph 33c of this order for the required mast lateral distance criteria.

b. The equipment shelter. Refer to paragraph 20 of this order for shelter information.

c. The equipment shelter is located 10 feet behind (in the direction opposite the approach threshold) and on the same reference line as the antenna mast.

d. If stray radiation is detected outside the equipment shelter, the inside wall of the equipment building nearest the mast may be covered with a copper mesh screen to minimize stray radiation effects. It may be necessary, where stray radiation is severe, to shield additional portions of the building. Equipment transportable shelters of metallic construction do not require screening. (See the latest edition of Order OA P 8200.1 Section 217, Engineering Support Tests.)

32. END-FIRE GLIDE SLOPE CRITERIA.

a. As mentioned earlier, the formation of the glide path is different for non-image end-fire glide slope systems, ending many concerns with the effects of terrain on the glide path performance. Actually, the principal purpose of the end-fire glide slope antenna is to provide conventional glide slope service at locations where conformance to the image system siting criteria is impractical or expensive At the present time an up-slope version of the end fire glide slope system is under development. Until the development effort is completed and the system is available for production, a terrain upslope of not greater than 1.0 degree should be considered as the practical limitation of the current standard system.

b. Operation. The end-fire glide slope antenna interfaces with the standard dual-frequency, glide slope station and serves as a substitute for the antenna mast, elements, and associated monitor probes and antennas. Two antennas, the front and rear course antennas, separated about 450 feet, form approximately 125-foot-long arcs about the antenna array phase center. The phase center is an imaginary point from which the antenna radiation in the far field appears to radiate and corresponds in some aspects to the base location of an image-type antenna mast. The phase center is nominally located directly opposite the runway point of intercept (RPI) at an approximate distance of 200 feet. The course antennas radiate RF with 90 and 150-Hz sidebands in quadrature which combine in space to produce an on-path signal at the desired glide slope angle about the runway approach direction. In addition, two clearance antennas radiate a 150-Hz modulated clearance rf carrier producing a radiation pattern minimum in space along the approach azimuth and increasing amplitude to the sides so that this signal will predominate to provide coverage of the glide path.

c. Terrain Effect. The radiation in the horizontal plane is very directional, which means that rising terrain with reflecting objects to the side about ±10 to ±15 degrees and beyond are of reduced importance. Except for high rising ground or obstructions below path, the terrain beyond the monitor antennas is of no concern. The signal strength is a function of the antenna height (typically 4 feet above the ground plane) which will decrease with a reduction of an effective antenna height, for example, with snow cover; however, with the implementation of the automatic gain control (AGC) monitor and its feedback loop the effects of snow cover as seen by the mid field RF monitor antennas are greatly reduced. This system improvement enables the end-fire antenna to be installed at locations previously considered unacceptable due to snow accumulation. When the end-fire antenna is to be installed at locations where the snow accumulation can be expected to exceed twelve (12) inches, consideration should be given to having the area identified as "EFGH" in figure 1-4 paved and included in the snow removal agreement with the airport sponsor.

d. Antenna Location. For the antenna location, an area is needed free from major obstructions (taxiways, long fences higher than 2 feet, high terrain mounds, and objects wider than 10 feet) preventing line of sight between the antennas and the monitor antennas in an area extending about 150 feet laterally with respect to the antenna phase center and extending about 1,000 feet forward from the rear antenna. Longitudinal slopes may be compensated for by adjusting the glide path angle and phase center location. Lateral runway shoulder slopes up to five percent may be compensated for by adjusting the antenna phase center and relative antenna spacing. However, a constant terrain slope is not required, so that, for example, water drainage may be provided without concern for the antenna operation.

e. End-Fire Glide Slope Equipment Layout (figure 3-8). The equipment shelter is located in line with the antenna phase center which, in turn, is nominally the RPI. The shelter could be located as close as 275 feet from the runway centerline. It is desirable to locate it close to the antenna array in order to keep the buried transmission and monitor rf cable lengths to a minimum. The course antennas consist of horizontally located continuous sections of slotted cable (special concentric pipe transmission line provided with radiation slots) held firmly in place about 4 feet above ground, with emphasis on maintaining constant relative dimensions between the rear and the front antennas. Each course antenna has a feed-point end connected to a buried rf transmission cable from the shelter and a load end towards the runway side for termination to an rf cable serving as monitor input at the shelter. Three mid-field monitor antennas are located approximately 800 feet in front of the antenna phase center. Three small clearance antennas are located between the course antennas, two serving as radiator antennas and one as a monitor antenna.

33. LOCATING THE GLIDE SLOPE FACILITY.

a. Definitions and terminology. Several terms and abbreviations are used when locating the glide slope facility (refer to figures 3-9, 3-22, 3-23 and 3-24).

Threshold (T). The beginning of that portion of the runway usable for landing.

Approach Surface Base Plane (ASBP). An imaginary horizontal reference plane at the threshold elevation.

Approach Surface Base Line (ASBL). An imaginary horizontal reference line formed by the interception of the ASBP and the vertical plane containing the runway centerline and centerline extended.

Glide Path Height (GPH). The height of the glide path above a reference point.

Extended Glide Path. Imaginary extension of the straight-line portion of the glide path coinciding with the glide path over the outer marker and intercepting the ASBL at a point not less than 775 feet down the runway from the threshold.

Glide Angle (θ). The elevation angle of the glide path with respect to the ASBP; ideally, the angle formed by the ASBL and the extended glide path.

Ground Point of Intercept (GPI). The point where the extended glide path intercepts the ASBL ; the GPI shall be not less than 775 feet from the threshold.

Threshold Crossing Height (TCH). The height of the extended glide path vertically above the threshold.

Runway Point of Intercept (RPI). The point where the extended glide path intercepts the runway centerline.

"d". Longitudinal distance between point "r" and the glide slope antenna (or point "m").

"d1" Distance from the threshold to the RPI. (Used only when the "d" does not coincide with the RPI distance.)

"D". Distance from the GPI to an obstruction.

"D_1". Distance from the GPI to the threshold.

"$D_{(t)}$". Distance from the threshold to an obstruction minus 200 feet.

"LC". Lateral perpendicular distance between the glide slope antenna and the runway centerline.

"m". The glide slope antenna mast location, or the end-fire antenna phase center.

"r". Reference point on terrain directly abeam a threshold at a lateral distance, LD.

"$S_{(i)}$". Slope of inner section approach surface, expressed as an integer; e.g., 34 for 34:1.

"WCH". Wheel Crossing Height.

b. When planning a glide slope, the initial step is to determine where the facility should be located in relation to the runway. In addition to considering the terrain conditions on either side of the runway, the location of potential glide slope interference should be considered. Of primary importance in this regard is the location of taxiways, aircraft holding aprons, and parking ramps. The glide slope should be located on the side of the runway free from such interference. If terrain or other factors preclude locating the facility away from these areas, it may be necessary to restrict the flow of ground traffic to prevent glide slope interference.

c. Lateral Distance Criteria.

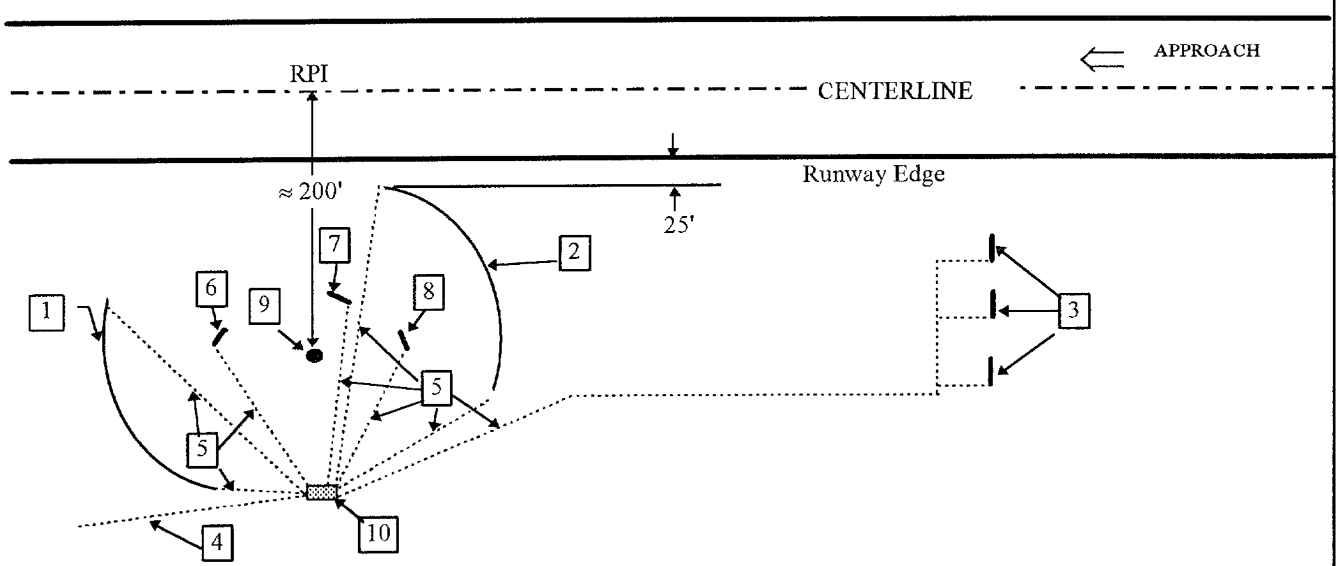
(1) The glide slope antenna mast shall be located on a longitudinal reference line that is parallel to the runway centerline and at a lateral distance as determined by applying the obstacle-free zone criteria (see figure 3-11). The antenna shall be located outside the OFZ and shall not penetrate the 3:1 plane. The glide slope should be located at the optimum lateral distance. The optimum location within the LD criteria shall be determined by the site analysis.

(2) If the antenna mast cannot be located within the above limits, an NCP may be requested for glide slopes which must be sited more than 650 feet from the runway centerline. The decision height may not be less than 250 feet for these glide slopes.

(3) In conjunction with the siting conditions, the required height of the glide slope antenna mast shall be considered when determining the lateral distance. (See figures 3-10, 3-11, and 3-12.) The glide slope antenna mast height shall comply with the lateral distance obstruction criteria. When applying the lateral distance criteria, the elevation of the runway centerline directly abeam of the antenna mast shall be used as the vertical reference point.

(4) The lateral distance shall comply with the OFZ criteria of AC: 150/5300-13, Airport Design, which states "The runway OFZ and approach OFZ widths are the greater of: 180 feet (54m), plus the wingspan of the most demanding airplane, plus 20 feet (6 m) per 1000 feet (300m) of airport elevation; or 400 feet (120 m)." (see figure 3-11.) For runways that are used exclusively by small aircraft, i.e., those of 12,500 lbs maximum certificated takeoff weight per paragraph 2 of AC 150/5300-13, the OFZ width shall be 300 feet. All glide slope antenna masts should be located a minimum of 400 feet from runway centerline.

(5) The lateral distance between the end-fire front antenna and the runway edge shall not be less than 25 feet. (See figure 1-4.)



LEGEND:

1. Rear Course Antenna
2. Front Course Antenna
3. Midfield Monitor Antennas
4. Buried Power Line
5. Buried RF Cables (and Power Cables when required for Obstruction Lights)
6. Rear Clearance Antenna
7. Front Clearance Antenna
8. Clearance Monitor
9. Phase Center
10. Equipment Shelter

FIGURE 3-8. TYPICAL END-FIRE GLIDE SLOPE EQUIPMENT LAYOUT

d. Longitudinal Distance Requirements.

(1) The final determination of the longitudinal distance is made in accordance with the criteria provided in Order 8240.47, Determination of Instrument Landing System Glidepath Angle, Reference Datum Height and Ground Point of Intercept. The information presented in the following subparagraphs and Appendix 4 will assist in making the initial determination at those sites that do not exhibit the ideal terrain conditions. This information is especially useful in determination of the proper antenna location in the case of category II/III glide slope facilities and the associated restrictive tolerance on the commissioned threshold crossing height (TCH). Where very complex terrain irrregularies exist, it may be necessary to conduct a preliminary site test utilizing mobile equipment and or request mathematical modeling assistance in accordance with paragraph 2 of Appendix 2.

(2) In conjunction with determining the lateral distance, the longitudinal distance, "d," of the antenna mast (or phase center in the case of the end-fire antenna) with respect to the point directly opposite the runway threshold should be ascertained. Several related parameters and requirements influence the determination of the optimum longitudinal distance:

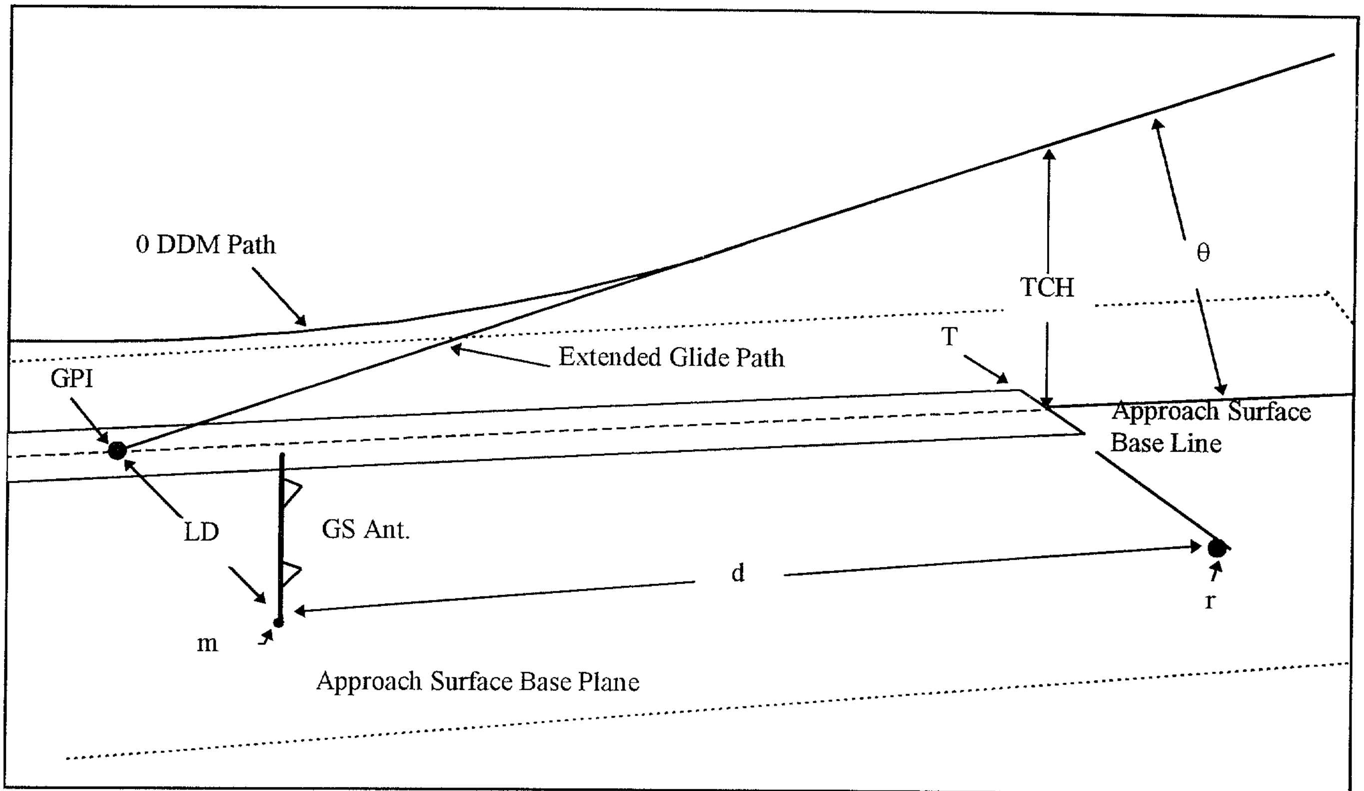


FIGURE 3-9. IDENTIFICATION OF GLIDE SLOPE SITING PARAMETERS

(a) the commissioned glide angle,

(b) threshold crossing height requirements,

(c) required obstruction clearance criteria,

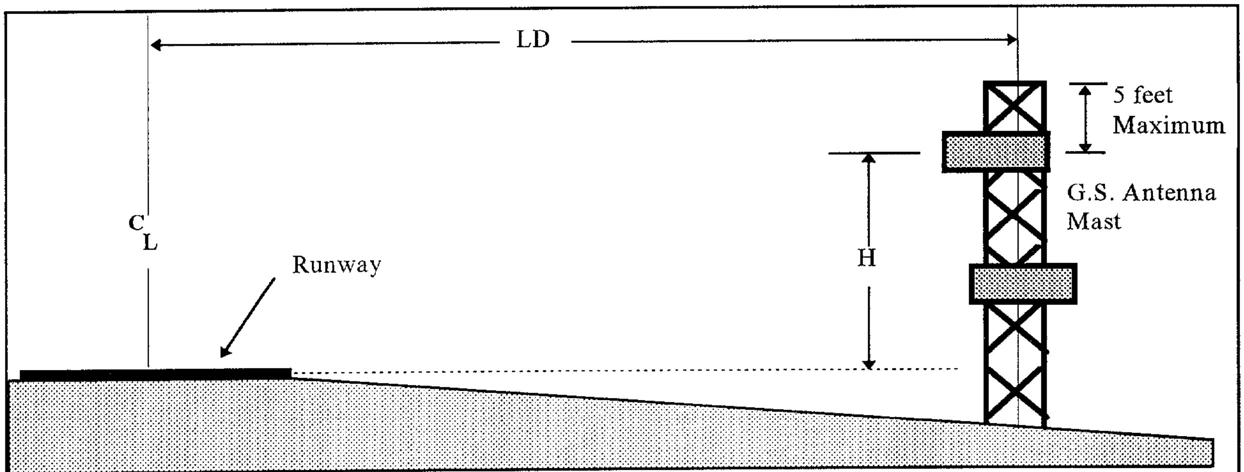
(d) the slope of the terrain along the longitudinal reference line, and

(e) the extent of smooth terrain in the site area and beyond the threshold.

(3) Several requirements are implicitly related, with each affecting the computation of the correct longitudinal distance and limiting the permissible values of the remaining items. However, by initially using the ideal or optimum values for the more critical items, the longitudinal distance which will satisfy the optimum conditions can be determined. Then, by incrementally adjusting the values and the longitudinal distance within the assigned limits, compliance with the remaining requirements can be attained..

(4) Where there is a limited amount of smooth terrain in front of the ideal location, the longitudinal distance should be increased, with a corresponding adjustment in the remaining parameters, within their defined limits, to provide the greatest extent of smooth terrain. In addition, where the smooth terrain is limited, a sideband reference, capture effect, or end-fire system will generally be required (see figure 3-8). If a sideband reference system is used, the lower antenna height requirements may permit a reduction in the lateral distance and, thereby, a possible increase in the extent of smooth terrain. Since a capture effect system requires a higher antenna mast than a null reference system, a greater lateral distance may be required.

(5) The glide slope shall be established to provide a measured glide angle within the limits of 2.75 to 3.04 degrees with an optimum value of 3.0 degrees. The threshold crossing height shall conform to the latest edition of Order 8260.34, Glide Slope Threshold Crossing Height Requirements.

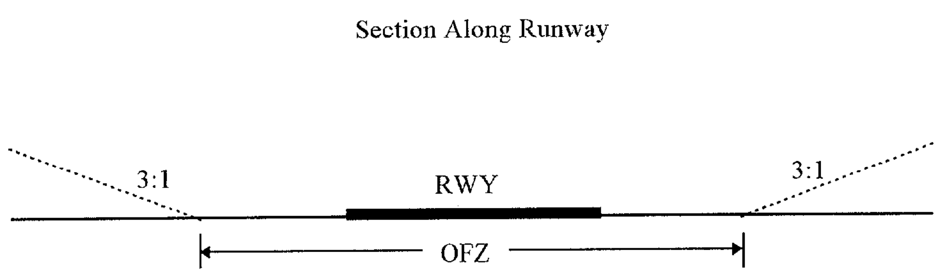


Notes:

LD is the lateral distance in a horizontal plane between the center of the glide slope antenna mast and the runway centerline.

H is the height of the upper glide slope antenna above the runway centerline elevation.

FIGURE 3-10. GLIDE SLOPE MAST LATERAL DISTANCE TERMINOLOGY



Note:

The runway OFZ and approach OFZ widths are the greater of : 180 feet (54m), plus the wingspan of the most demanding aircraft, plus 20 feet (6m) per 1,000 feet (300m) of airport elevation; or, 400 feet (120m) (see paragraph 27c.(4).

The glide slope mast shall not violate the 3:1 plane.

FIGURE 3-11. GLIDE SLOPE MAST LATERAL DISTANCE CRITERIA

(6) The ideal longitudinal distance, "d," should be determined by one of the formulas derived in the following examples, whichever is applicable to the particular siting conditions.

(a) If the terrain encompassing the glide slope site is essentially flat (zero terrain slope, or of constant elevation from point "r" to the general area of the site which is about 800 to 1400 feet from point "r"), "d" is determined by application of the general formula (refer to figure 3-13).

$$d \tan\theta = TCH$$

$$d = \frac{TCH}{\tan\theta} \qquad (3\text{-}1)$$

For example, the conditions of a 50-foot threshold crossing height and a 3.0-degree glide angle:

$$d = \frac{50\ feet}{\tan 3.0^\circ}$$

$$d = 954\ feet$$

For a 55-foot threshold crossing height and a 3.0 degree glide angle:

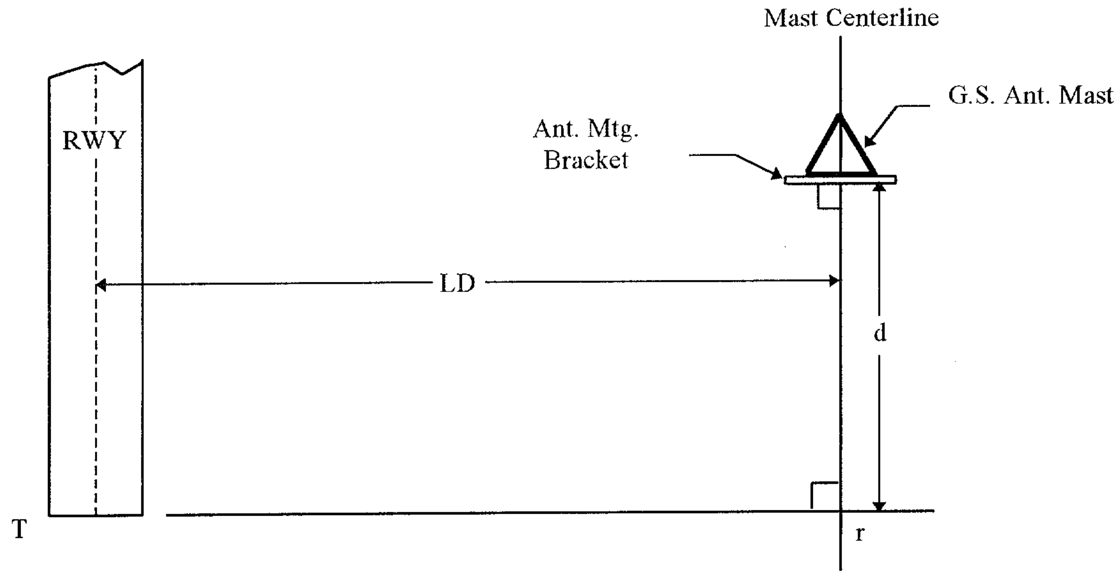
$$d = \frac{55\ feet}{\tan 3.0^\circ} = 1049\ feet$$

(b) Few airports will have the ideal runway and glide slope terrain conditions, a smooth horizontal surface in the ASBP. Due to the natural terrain and airport construction, most runways will have some gradient or slope. This gradient will, of course, result in an elevation difference between the threshold and the RPI. Since the RPI is determined by the longitudinal location of the glide slope mast, this elevation difference must be considered when determining the distance, "d." The equation (3-1) for ideal conditions may be expanded to include this elevation difference, "e," (see figure 3-14).

$$d \tan\theta = TCH + e \qquad (3-2)$$

$$d = \frac{TCH + e}{\tan\theta}$$

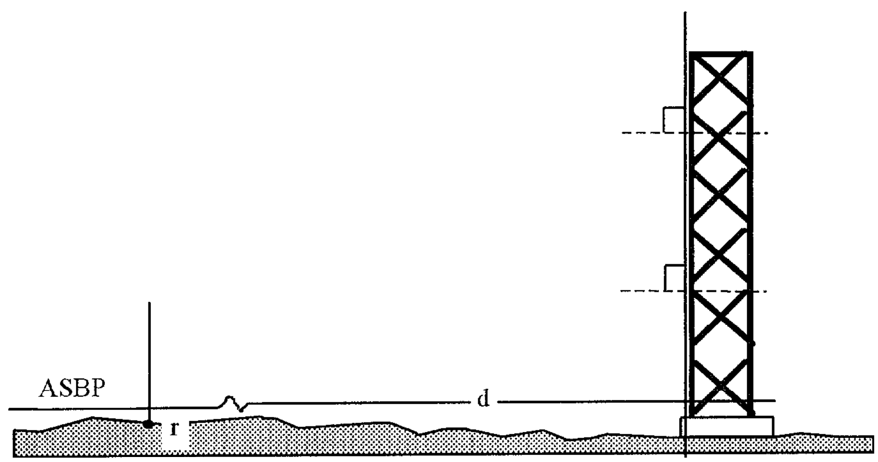
$$= \frac{TCH}{\tan\theta} + \frac{e}{\tan\theta} \qquad (3-3)$$



Note:

Mast centerline shall be parrallel to runway centerline

a. Top View Details for Lateral Distance Criteria



Note:

The plane containing front edge of the mounting brackets shall be perpendicular to the ASBP and line LD

b. Side View Details for Longitudinal Distance Criteria

FIGURE 3-12. LATERAL DISTANCE CRITERIA DETAILS

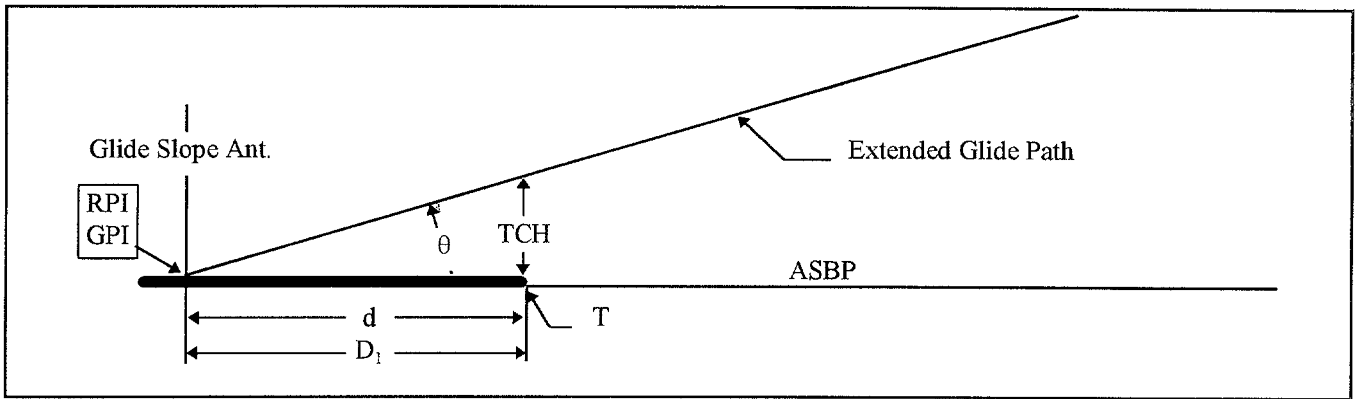


FIGURE 3-13. GLIDE SLOPE SITE WITH IDEAL TERRAIN

For a given threshold crossing height and glide path angle, equation (3-3) may be further simplified. For example, for the TCH and θ of 50 feet and three degrees respectively:

$$d = 954\,feet \quad + \quad 19.1e$$

For a TCH of 55 feet and a θ of 3.0 degrees:

$$d = 1049\,feet \quad + \quad 19.1e$$

(c) Since equation (3-3) contains two unknown terms, "d" and "e," a direct solution is not possible. However, by assuming a longitudinal distance and determining the corresponding value for "e" from a topographical map, the glide path angle required for a given threshold crossing height, or vice versa, can be determined. This procedure may require several computations using different assumed values for "d" to find the optimum longitudinal distance.

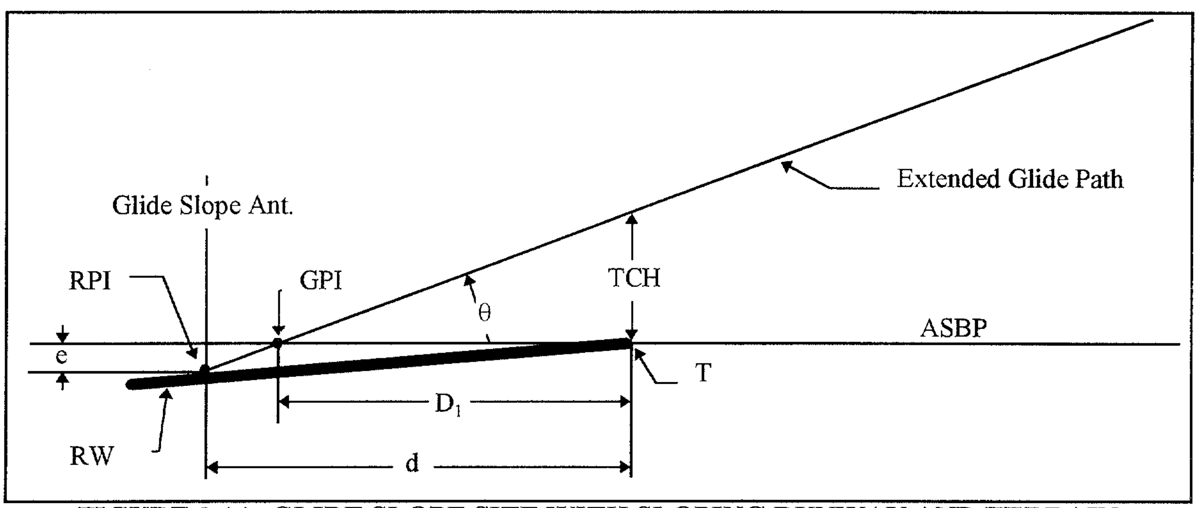


FIGURE 3-14. GLIDE SLOPE SITE WITH SLOPING RUNWAY AND TERRAIN

(d) If the runway has a linear gradient or slope between the threshold and the general area of the RPI, and the terrain between reference point "r" has the same slope, the solution for the correct longitudinal distance is considerably simplified. Where this is the case, the change in elevation can be expressed as a function of the slope rate and the distance "d":

$$e = s \times d \tag{3-4}$$

where: s = terrain slope in feet/hundred feet and is positive if the threshold elevation is higher than that of the RPI and negative if the threshold elevation is lower than that of the RPI.

Using the above expression in equation (3-2) :

$$d \tan\theta = TCH + e \tag{3-2}$$

$$d \tan\theta = TCH + (s \times d)$$

$$d = \frac{TCH}{\tan\theta - s} \tag{3-5}$$

(e) Application of equation (3-5) is provided in the examples depicted in figures 3-15 and 3-16. Figure 3-15 shows a site with a positive terrain slope; figure 3-16 depicts a site with a negative terrain slope.

> NOTE: With ideal terrain, "d" is equal to "D_I." Where the longitudinal terrain is sloping, "D_I" will be greater than or less than "d" depending on whether the slope is negative or positive, respectively.

(f) Where the runway does not have a linear slope, an empirical determination of the GPI may be required. The solution may be simplified by initially determining the average slope from the elevation difference between the threshold and an assumed longitudinal distance, and then using this average slope in equation (3-5).

$$S_{avg} = \frac{e_T - e_d}{d} \tag{3-6}$$

(g) An initial assumed distance may be determined by adding or subtracting an estimated amount from the ideal distance ascertained from equation (3-1) for the desired operating parameters. To determine if the computed distance is correct, the actual elevation difference between the threshold and this distance should be determined. The computed distance and the actual elevation difference must be compatible with the operating parameters in accordance with equation (3-2). If this requirement is not met, the procedure should be repeated for different assumed slopes until equation (3-2) is satisfied. An example of these computations is depicted in figure 3-17.

(7) Terrain gradients in ,the lateral direction also affect the location of the glide slope antenna. The need to compensate for lateral elevation difference depends upon the rate and consistency of the lateral slope.

(a) The most desirable condition, except for an ideal horizontal plane, is a lateral terrain which slopes at a constant rate within the recommended limits. This type of terrain condition results in two significant parameter changes which have an equal and opposite effect on the siting requirements. The upslope from the glide slope mast causes a corresponding angular rotation of the glide slope radiation lobes and, therefore, an apparent increase in the height of the extended glide path. However, the slope also causes a lower elevation of the glide path origin, the base of the antenna mast and, therefore, a downward shift in the extended glide path. The resulting angular position of the extended glide path is approximately identical to that which would be obtained with an ideal horizontal ground plane. The effects of this type of terrain slope, which are depicted in figure 3-18, can therefore be ignored when selecting a glide slope site.

(b) At some locations, particularly where the runway has been constructed on landfill, an elevation difference between the runway and the glide slope site without a constant intervening terrain gradient may be encountered. Although this condition is undesirable and will probably restrict the operational use of the facility, it may still be advantageous to install a glide slope to improve the approach guidance. To assure establishment of the optimum parameters at this type of location, however, it is necessary to compensate for the lateral elevation difference as indicated in figures 3-19 and 3-20.

(c) At the site depicted in figure 3-20 the elevation difference "a" is 6 feet with a threshold crossing height of 53 feet and a glide path angle of 3.0 degrees. The following errors would result unless the elevation difference was considered when determining the glide slope location:

Required Values: $\theta = 3.0$ degrees; TCH = 53 feet

$d = 53$ feet/tan 3.0 degrees = 1011 feet

Actual Values : $\theta = 3.0$ degrees; $d = 1011$ feet

TCH = 53 feet - 6 feet = 47 feet

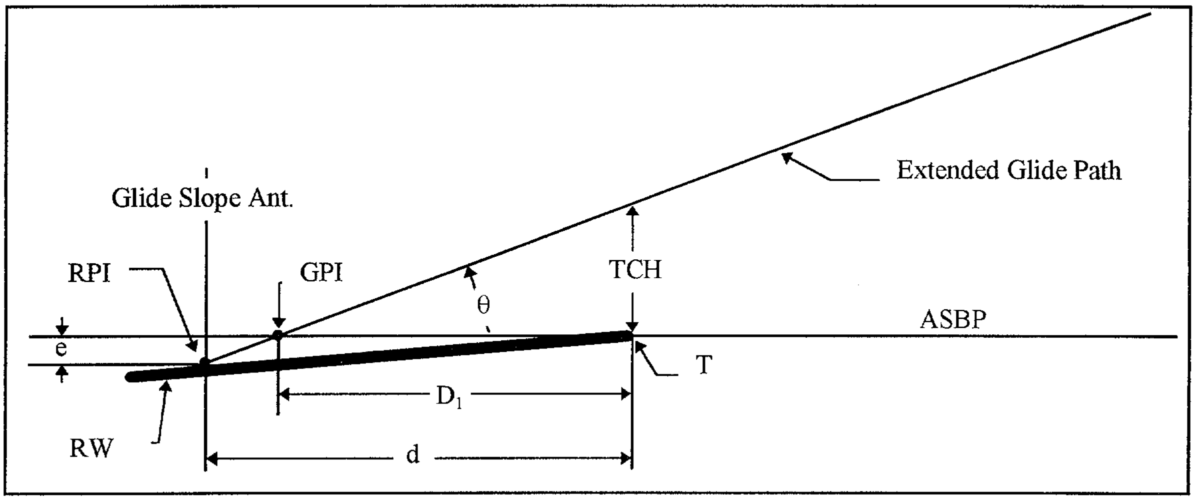
Dl = 47 feet/tan 3.0 degrees = 897 feet

The correct glide slope location for this type of site should be determined by adaptation of equation (3-2), as depicted below, and figure 3-20.

$$d \tan \theta = TCH + e \qquad (3\text{-}2)$$
$$d \tan \theta = TCH + a \qquad (3\text{-}2a)$$
$$d = (53 \text{ feet} + 6 \text{ feet}) / \tan 3.0 \text{ degrees}$$
$$= 1126 \text{ feet}$$
$$D_I = 1011 \text{ feet}$$

(8) At locations where an elevation difference between the threshold and the glide slope site is due to both a lateral terrain gradient and a runway or longitudinal slope, the correct glide slope antenna location can be determined from the combined effect of the terrain gradient in each direction.

(a) For example, if a runway has a longitudinal slope of -1.5 percent and the lateral terrain slopes linearly at a 0.5 percent rate, as depicted in Figure 3-21, with a threshold crossing height of 50 feet and a glide path angle of 3.0 degrees:



(a) A site has a longitudinal terrain slope of 0.5 percent; determine "d" required to establish the optimum glide path angle of 3.0 degrees and a threshold crossing height of 50 feet.

given: s = .005, θ = 3.0°, TCH = 50′

$$d = \frac{TCH}{\tan\theta - s}$$

$$d = \frac{50}{.05241 - .005}$$

$$d = 1055 \textit{ feet}$$

(b) Determine "d" if the terrain slope is 1.0 percent and a glide path angle of 3.0 degrees with a threshold crossing height of 55 feet.

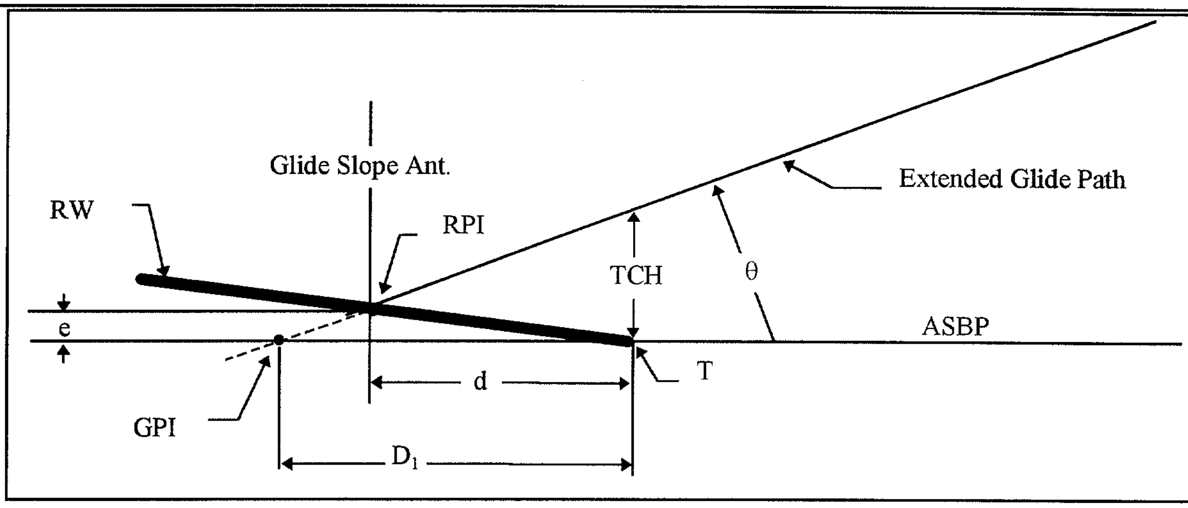
given: s = .01, θ = 3.0°, TCH = 55′

$$d = \frac{55}{\tan 3° - .01}$$

$$d = \frac{55}{.05241 - .01}$$

$$d = 1297 \textit{ feet}$$

FIGURE 3-15. GLIDE SLOPE SITE WITH POSITIVE TERRAIN SLOPE



(a) A site has a longitudinal terrain slope of 0.5 percent; determine longitudinal distance required to establish the optimum conditions of θ = 3.0 degrees and, a TCH = 50 feet.

given: s = -0.005, θ = 3.0°, TCH = 50′

$$d = \frac{TCH}{\tan\theta - s}$$

$$d = \frac{50}{.05241 - (-.005)}$$

$$d = 871 \textit{ feet}$$

(b) Determine "d" if the terrain slope is -.75 percent and a glide path angle is 3.0 degrees with a threshold crossing height of 52 feet.

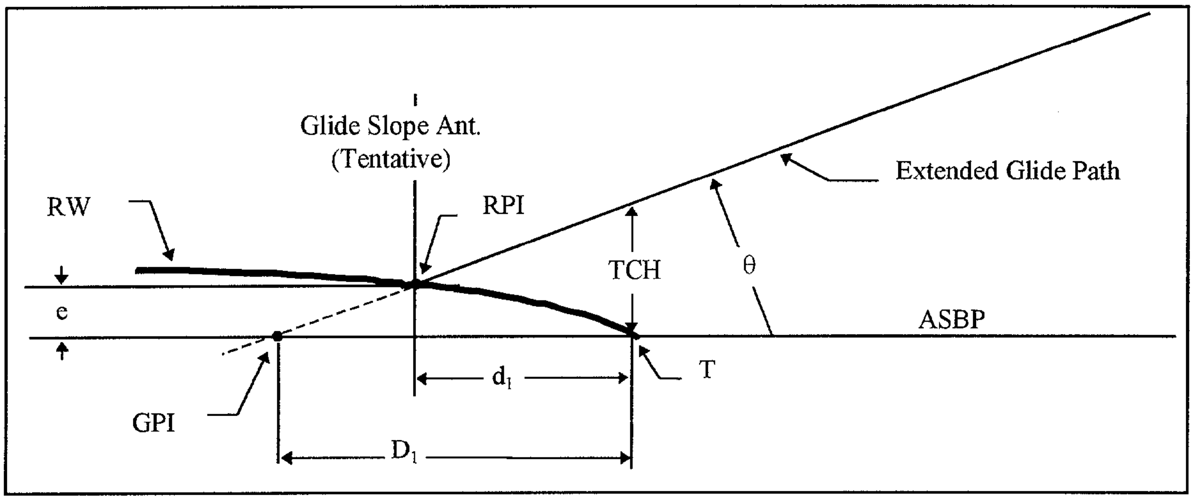
given: s = -0.0075, θ = 3.0°, TCH = 52′

$$d = \frac{52}{\tan 3° - (-.0075)}$$

$$d = \frac{52}{.05241 + .0075}$$

$$d = 868 \textit{ feet}$$

FIGURE 3-16. <u>GLIDE SLOPE SITE WITH NEGATIVE TERRAIN SLOPE</u>



A glide slope of 3.0 degrees and a TCH of 52 feet is to be established at the depicted site, which has a nonlinear terrain slope. Initially, the longitudinal distance with ideal terrain is determined.

From formula (3-1): d = 992 feet (Ideal)

Since the runway has a negative gradient, a distance less than the ideal should be used:

d_1 = 950 feet (first assumption)

From the topographical data the relative elevation at "d" is ascertained. Assume this elevation to be 8 feet. An average slope is determined from equation (3-6).

$$s_{avg} = \frac{e_T - e_d}{d_1} = \frac{0-8}{950} = -0.0084$$

Using equation (3-5) the longitudinal distance for a constant slope equal to the average slope is computed.

$$d = \frac{TCH}{\tan\theta - s}$$

$$d_1 = \frac{52}{.05241-(-.0084)} = 855\ feet$$

Next the required elevation at "d_1" is determined using equation (3-2).

$$d \tan\theta = TCH - e$$

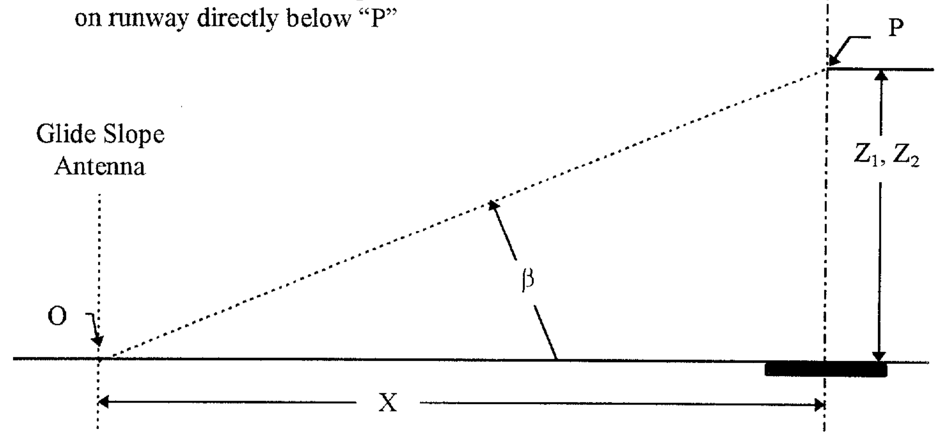
$$855 \tan 3.0° = 52 - e$$

$$e = 7.2\ feet$$

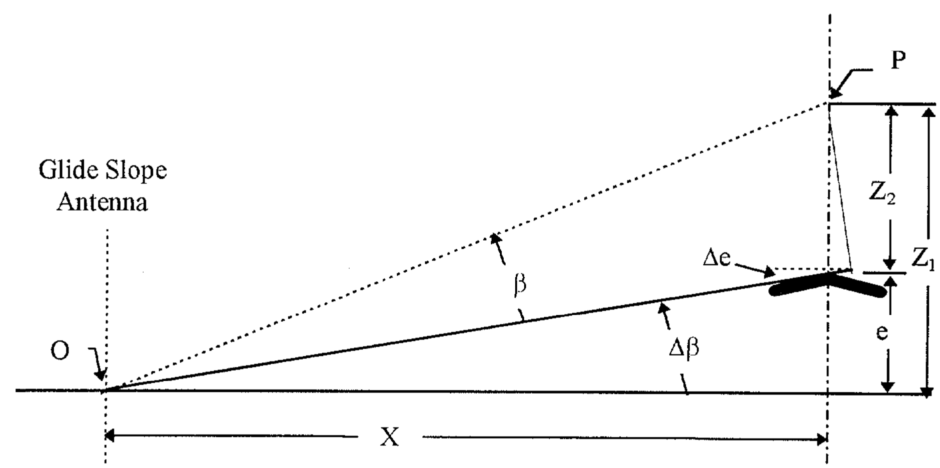
If the relative elevation at "d_1" equals this value (7.2 feet), then the computed distance is satisfactory. If the actual elevation differs considerably from the computed requirement, then a second distance should be assumed and the computations repeated so that the distance and elevation correlate in equation (3-2).

FIGURE 3-17. SITE WITH IRREGULAR SLOPE

P - point on extended glide path
O - origin of glide path
X - distance between "O" and point on runway directly below "P"
Z_1 - elevation of "P" above origin
Z_2 - Elevation of "P" above runway



a. Ideal lateral terrain: $Z_1 = Z_2 = X \tan \beta$



b. Sloping lateral terrain (within limits of grading criteria)

$Z_1 = X \tan (\beta + \Delta\beta)$
$Z_2 = Z_1 - e$ (Δe insignificant)
$e = X \tan \Delta\beta$
$Z_2 \approx X \tan \beta$

FIGURE 3-18. EFFECT OF SLOPING LATERAL TERRAIN ON GLIDE SLOPE SITING

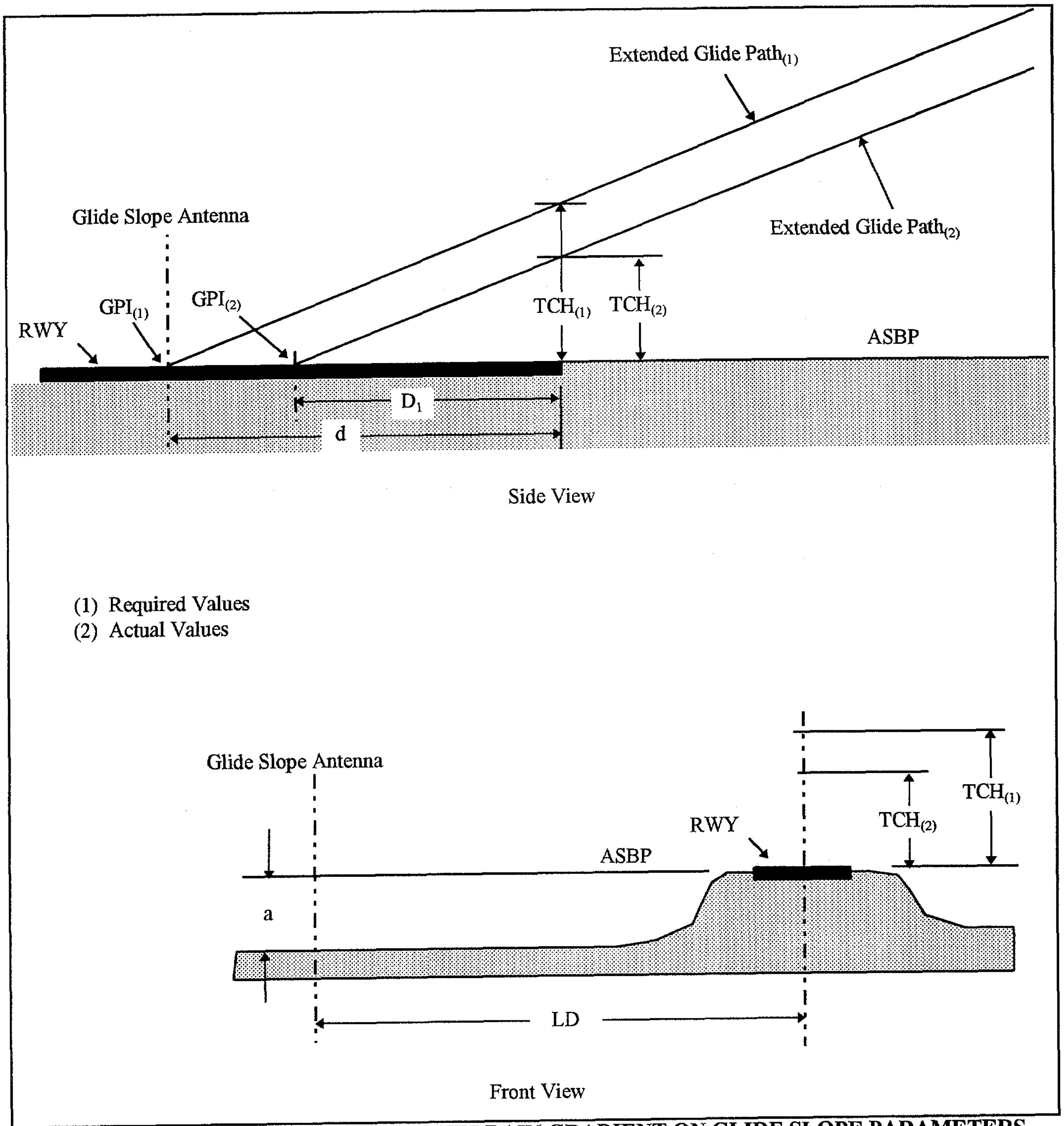


FIGURE 3-19. EFFECT OF LATERAL TERRAIN GRADIENT ON GLIDE SLOPE PARAMETERS

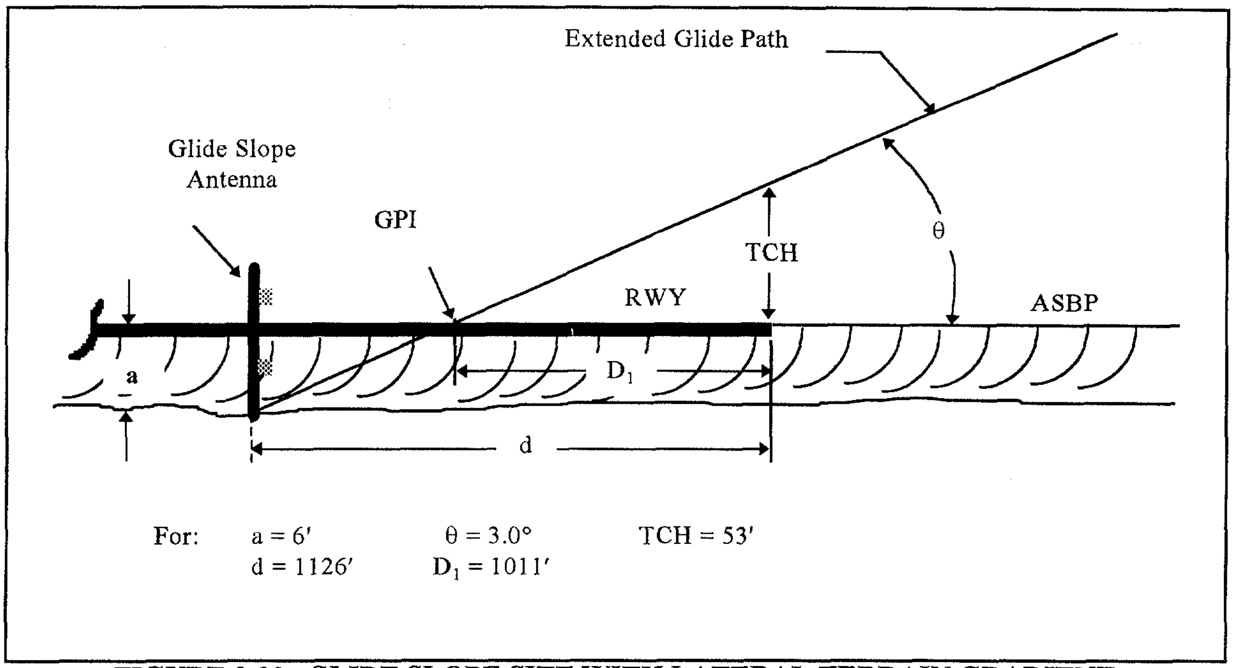


FIGURE 3-20. GLIDE SLOPE SITE WITH LATERAL TERRAIN GRADIENT

First, determine the longitudinal slope:

$$d = \frac{TCH}{\tan\theta - s}$$

$$= \frac{50\ feet}{\tan 3° - (-.015)} \qquad (3\text{-}5)$$

$$= 742 \text{ feet}$$

Then the lateral slope: If the lateral terrain has a smooth constant slope, within the grading criteria limits, correction for the lateral slope is not required.

Finally, combine the two distance measurements. The glide slope location, in this example, would be that determined by correction for the longitudinal slope only:

$$d = 742 \text{ feet} + 0 = 742 \text{ feet}$$

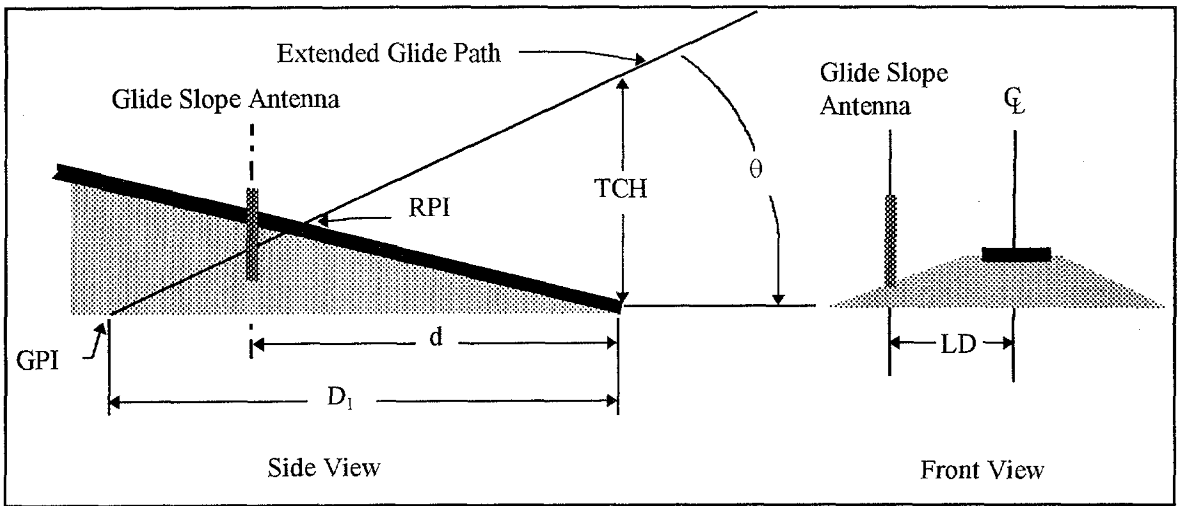


FIGURE 3-21. GLIDE SLOPE SITE WITH LONGITUDINAL AND LATERAL SLOPE

(b) The glide slope location depicted in figure 3-22 consists of a runway with a negative slope of 1.0 percent and a nonlinear lateral slope that results in a site which has a 4-foot lower elevation than the runway. The threshold crossing height is 50 feet with a 3.0-degree glide path angle. The longitudinal distance may be determined by adapting the previous equations.

$$d = \frac{TCH}{\tan\theta - s} \qquad (3\text{-}5a)$$

$$d = \frac{TCH + a}{\tan\theta - s}$$

$$d = \frac{50 + 4}{\tan 3° - (-.01)}$$

$$= 865 \text{ feet}$$

f. <u>Except at locations with a lateral terrain gradient</u>, for a given glide path angle and threshold crossing height, the distance "D_1" between the threshold and the GPI remains the same regardless of the longitudinal terrain. The importance in establishing the location of the GPI is its function as the reference point for determining the Required Obstruction Clearance (ROC) (see paragraph 37).

g. <u>In addition to locating the glide slope facility</u> to compensate for terrain effects on the operational parameters, consideration shall be given to the deviation of the ground-reflected signal from its ideal path. In the discussion of the antenna concept and Fresnel zone theory it was assumed that the ground reflection plane was horizontal and a perfect reflector. With sloping terrain, however, the actual glide angle will differ from the theoretical angle based on ideal terrain conditions (see figure 3-23).

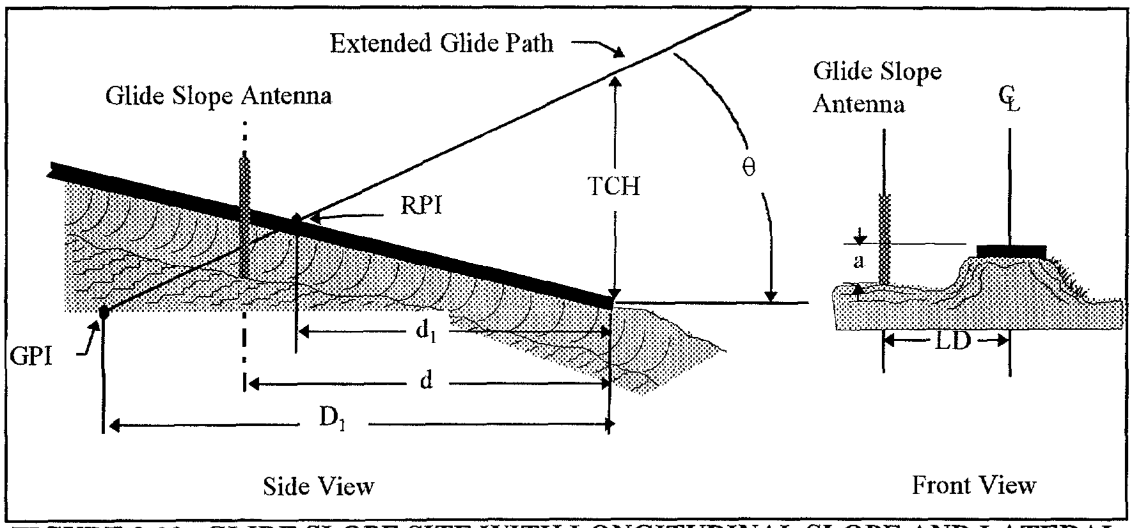


FIGURE 3-22. GLIDE SLOPE SITE WITH LONGITUDINAL SLOPE AND LATERAL GRADIENT

To establish the desired glide angle, an adjustment in the glide slope antenna height is required. For example, if the terrain slopes downward 0.5 degrees and a 3.0 degree glide angle is desired, the antenna height necessary to establish a 3.5 degree glide angle with ideal terrain conditions would be required. Conversely, with an upward slope of 0.3 degrees, the antenna would be set for 2.7 degrees if a 3.0 degree glide angle was desired (see the latest edition of Order 6750.54, Electronic Installation Instructions For Instrument Landing System (ILS) Facilities).

h. The optimum site, glide slope system, and operational parameters for each establishment or relocation shall be determined by a thorough engineering analysis of the particular siting conditions in accordance with the principles described in this handbook. Where severe site conditions are encountered, a site test may be conducted to measure the deviations from the ideal path and off-path clearances and to determine the exact facility site. Where establishment of a satisfactory glide slope requires deviation from the siting criteria or operational parameters, an approved NCP shall be obtained prior to commissioning the facility.

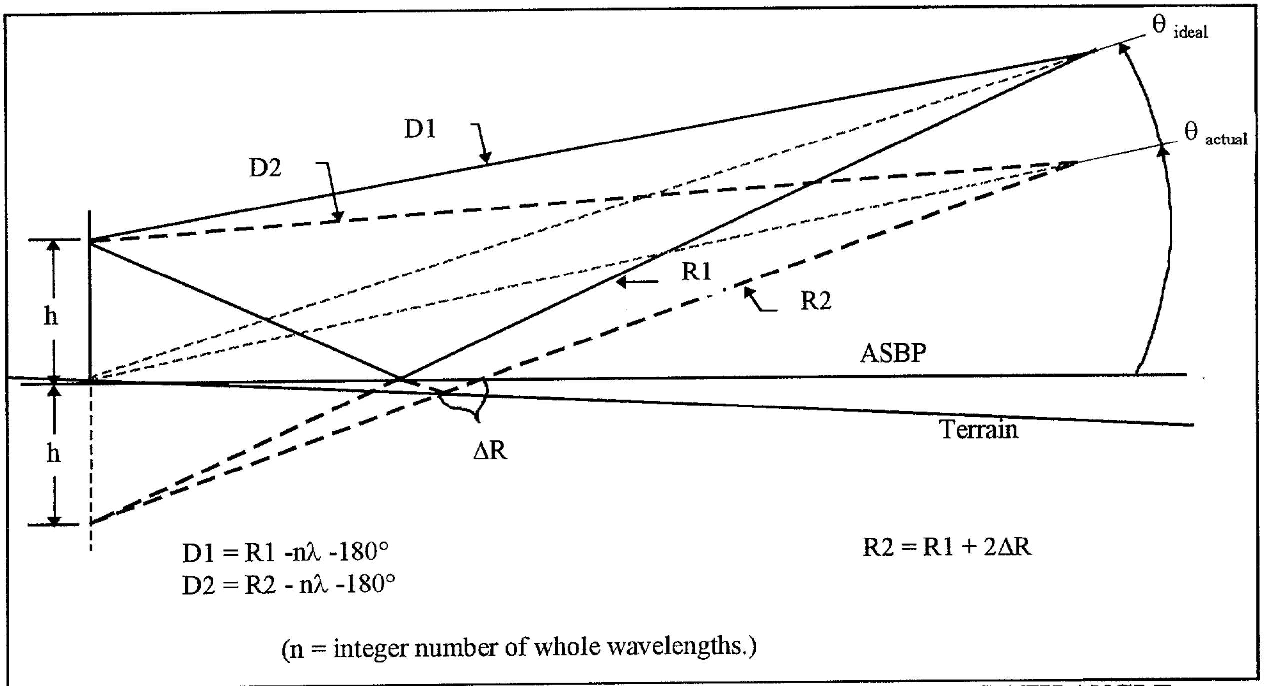


FIGURE 3-23. EFFECT OF SLOPING TERRAIN ON IDEAL GLIDE PATH ANGLE

34. INSTALLATION OF END-FIRE GLIDE SLOPE ANTENNA. Refer to FAA Drawings D-6226-1 and D-6226-2, End-Fire Glide Slope Antenna Installation Layout, for information on determining the phase center location after the GPI is identified.

35.-36. RESERVED.

37. REQUIRED OBSTRUCTION CLEARANCE (ROC).

a. The Required Obstruction Clearance criteria shall be followed when establishing a glide slope facility. The ROC is the required minimum vertical separation between the glide path and a physical obstruction located at a given point in the final approach zone. At the point of obstruction, the required clearance is equal to the difference between the elevation of two imaginary inclined planes extending from the ASBP into the approach zone. The upper plane originates at the GPI and extends outward along the extended glide path for a distance of 15 miles or until the glide slope intercept point, whichever is the lesser distance. The lower plane is formed by the final approach surface.

b. Since the obstruction clearance is a function of the elevation of the final approach surface, which differs in origin and slope in different sectors of the approach, a different procedure for determining the ROC must be used for each of the final approach sectors. For this purpose, the final approach area has been divided into three zones (see figure 3-24). The zone limits and the method of determining the ROC for each zone are:

(1) Zone 1 originates in the ASBP at a point 200 feet outward from the threshold and extends to the middle marker (MM) or to the decision height (DH) point, whichever is further from the threshold. The ROC in Zone 1 is equal to the difference in the elevation of the extended glide path and that of the approach surface inner slope $S_{(i)}$, at the point of the obstruction, as determined by the following formula (see figure 3-26 for values of $S_{(i)}$) :

$$ROC_1 = (d \tan\theta) - \frac{D_{(t)}}{S_{(i)}}$$

(2) Zone 2 begins at the MM or DH point, whichever is further from threshold, and extends outward to a point 10,975 feet from the GPI. The ROC in Zone 2 is approximately equal to the difference in the elevation of the glide path and that of the approach surface inner slope at the point of the obstruction. The Zone 2 ROC shall be determined by the following formula:

$$ROC_2 = 0.02336D + 20\,feet$$

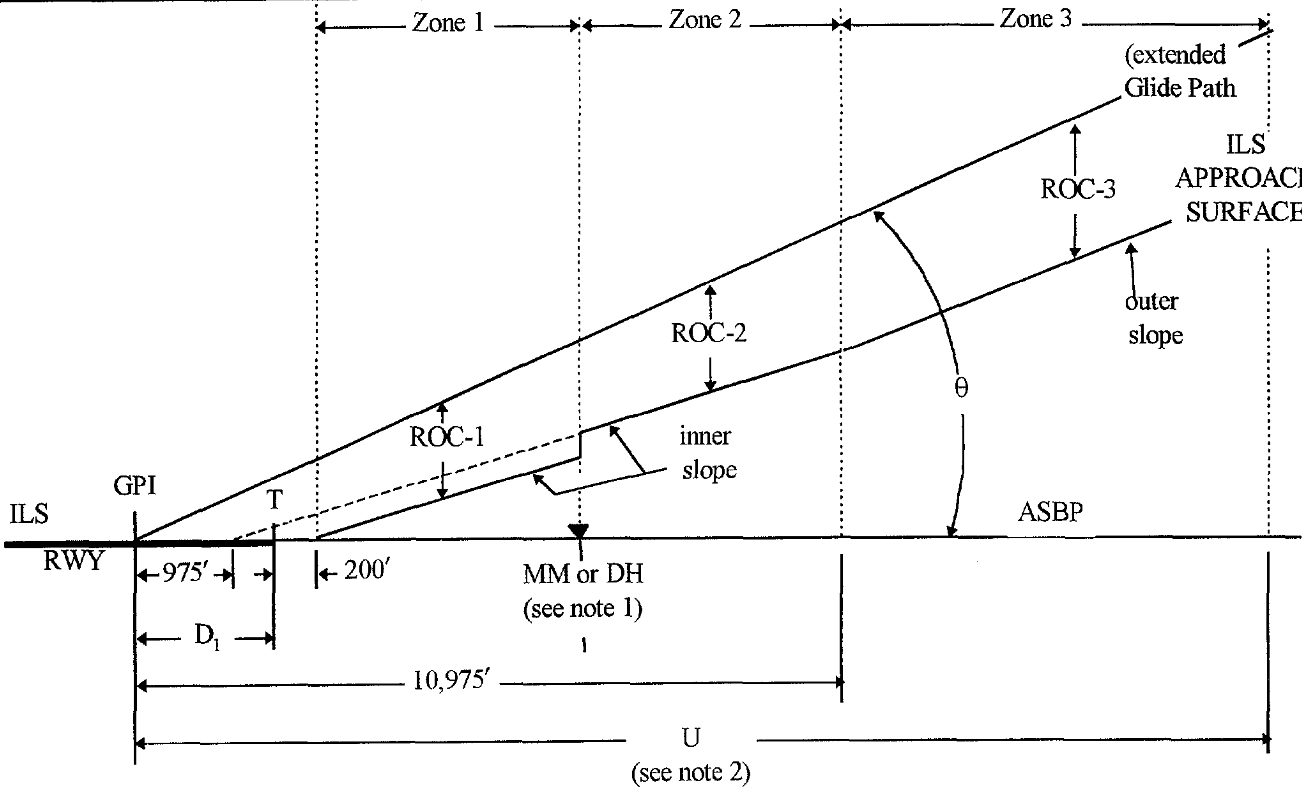
(3) Zone 3 starts at a point 10,975 feet from the GPI and extends outward to the glide slope intercept or a distance of 15 miles, whichever is less. The Zone 3 ROC is approximately equal to the difference in the elevation of the glide path and that of the approach surface outer slope at the point of the obstruction. The Zone 3 ROC shall be determined by the following formula:

$$ROC_3 = 0.01866D + 75\,feet$$

c. For determining the effect of the ROC criteria on a glide slope's location and operating parameters, it is advantageous to consider the site as falling into one of three classifications:

(1) Approach zone free of obstructions. If there are no obvious penetrations of the approach surface by obstructions, extensive consideration of the ROC is not necessary.

(2) Marginal obstruction penetration(s). If the penetration of the approach surface by an obstruction appears to be slight or marginal, the tentative glide slope should be determined in accordance with the preceding paragraphs. When a tentative glide path has been established, conformance to the ROC may then be determined. If necessary, slight adjustments may be made in the facility's location or glide angle or in the TCH to obtain compliance with the ROC.



NOTES:

1. Zone 1 terminates and Zone 2 begins at the Middle Marker or Decision Height, whichever is the greater distance from threshold.
2. Zone 3 extends to the glide slope intercept point or 15 miles, whichever is the lesser distance.

FIGURE 3-24. REQUIRED OBSTRUCTION CLEARANCE ZONES FOR THE ILS GLIDE SLOPE

ZONE	INNER BOUNDARY	OUTER BOUNDARY	CRITERIA
1	Point 200 feet outward from threshold.	The MM or DH pointer whichever is farther from the threshold	$ROC_1 = D\tan\theta - \frac{D_{(t)}}{S_{(I)}}$
2	MM or DH point (termination of Zone 1).	The point which is 10,975 feet outward from the GPI.	$ROC_2 = .02366D + 20 feet$
3	The point which is 10,975 feet outward from the GPI (termination of Zone 2).	The lesser of the distance to the glide slope intercept point or 15 nmi. from threshold.	$ROC_3 = .01866D + 75 feet$

FIGURE 3-25. TABULATION OF ROC CRITERIA

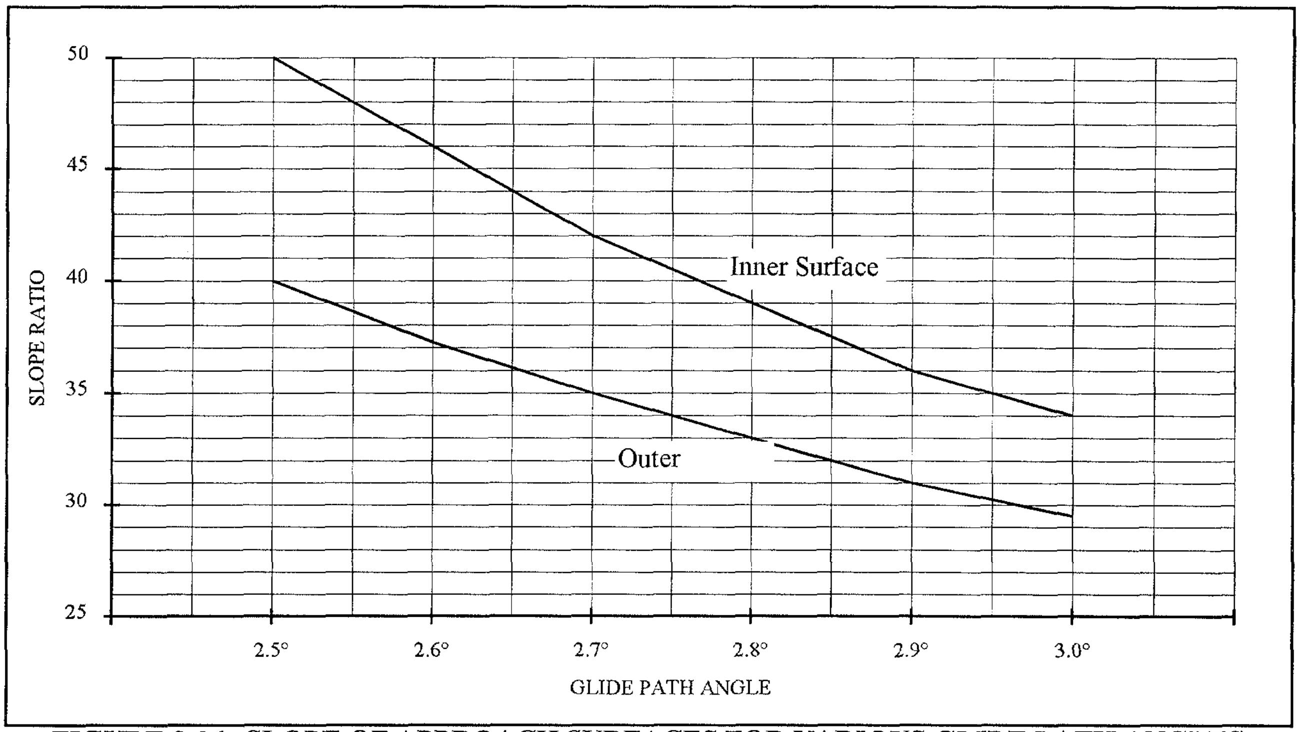


FIGURE 3-26. SLOPE OF APPROACH SURFACES FOR VARIOUS GLIDE PATH ANGLES

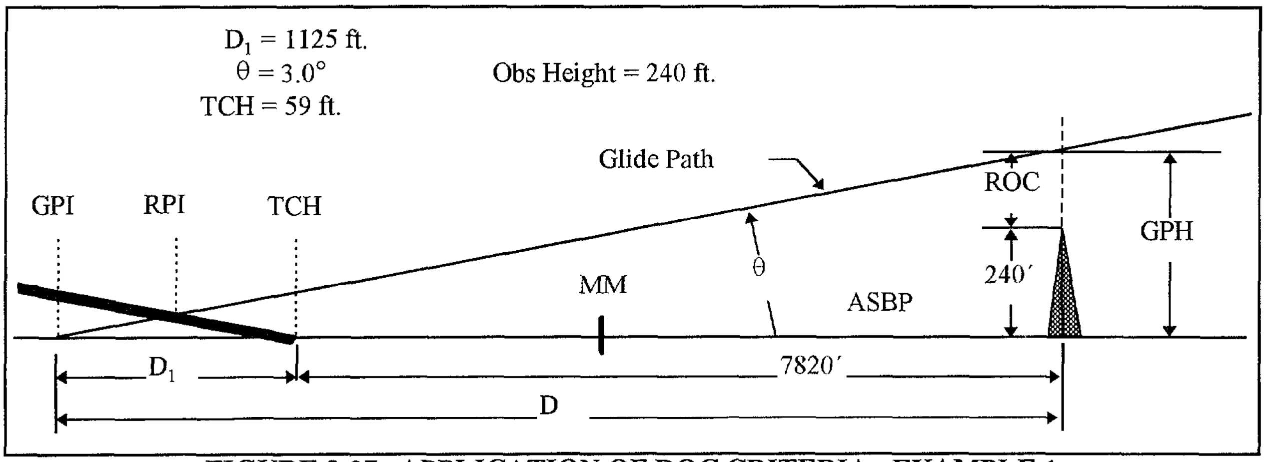


FIGURE 3-27. APPLICATION OF ROC CRITERIA - EXAMPLE 1

(3) Obvious obstruction penetration(s). When the penetration of the approach surface by an obstruction is obvious, the ROC for the limiting obstruction should be approximated first (for a tentative distance "D") and the glide angle and facility location which will provide the required clearance then determined from this information.

d. To determine whether a tentative glide slope location and operating parameters will provide a glide path which conforms to the ROC criteria, the following procedure should be implemented:

(1) Determine distance "D" between the tentative GPI and the obstruction(s).

(2) Compute the ROC at this distance by using the appropriate formula for the zone in which the obstruction (extended) is located.

(3) Compute the elevation of the (extended) glide path above the obstruction:

$$\text{Glide Path Elevation} = D \tan \theta$$

(4) Determine the vertical separation above the obstruction that the tentative glide path will provide. The vertical separation or actual obstruction clearance must be equal to or greater than the ROC:

$$D \tan \theta - \text{Obstruction Height} = \text{ROC}$$

e. Controlling Obstruction. If more than one obstruction is present in the approach zone, the ROC should be computed for each obstruction since all obstructions shall conform to the criteria. The obstruction that requires the highest glide angle and/or the greatest distance "D" to the facility to provide the ROC, or that limits the decision height because it does not comply with the ROC, is designated as the "controlling obstruction."

f. Examples of applying the Required Obstruction Clearance criteria.

(1) A glide slope has been tentatively sited as shown in figure 3-27. If must now be determined whether the proposed glide slope will provide the ROC above a 240-foot obstruction located 7820 feet from the threshold.

$$\begin{aligned} D &= 1125 \text{ feet} + 7820 \text{ feet} \\ &= 8945 \text{ feet} \end{aligned}$$

Since the obstruction is located in Zone 2, ROC_2 criteria is applicable:

Required Clearance	Actual Clearance
$(ROC_2) = 0.0237\,D + 20$ feet	Clear. = GPH - obstruction Height
$= (0.0237 \times 8945) + 20$	$= 8945 \tan 3.0° - 240$ feet
$= 232$ feet	$= 229$ feet

The clearance provided by the proposed glide slope is obviously not acceptable, and an adjustment in one or more of the parameters is necessary. It is possible to provide the ROC by retention of the desired value for either Dl, θ, or the TCH and adjustment of the other two values (i.e., retain θ and adjust D_1 and the TCH) :

(a) Retain D_1 and adjust TCH and θ :

$$\theta = \tan^{-1}\left(\frac{ROC + obstruction\ height}{D}\right)$$

$$\theta = \tan^{-1}\left(\frac{232\ feet + 240\ feet}{8945\ feet}\right)$$

$$\theta = 3.02°$$

TCH = 1125 feet tan 3.02 degrees

= 59.3 feet

(b) Retain TCH and adjust θ and D_1 :

$$\tan\theta = \frac{472}{D} = \frac{59}{D_1}$$

$$D = 8945\ feet$$

$$Tan\,\theta = \frac{472}{8945} = .05277$$

$$\theta = 3.02°$$

$$D_1 = \frac{59}{\tan 3.02°} = \frac{59}{.05277} = 1118\ feet$$

(c) Retain θ and adjust TCH and D_1:

$$D = \frac{472\ feet}{\tan 3°} = 9006\ feet$$

$$D_1 = D - 7820\ feet = 1186\ feet$$

$$TCH = 1186 \tan 3° = 62\ feet$$

It is readily apparent that the most feasible method of satisfying the ROC criteria is to adjust the glide angle and threshold crossing height. In this example, it would be the only permissible method since the alternate solutions would require a violation of the permissible limits on either the glide angle or the threshold crossing height. A compromise solution involving adjustment of all three parameters is, of course, possible and is generally recommended; however, it is apparent that increasing the glide angle provides the largest increase in the glide path height.

(2) A 400-foot obstruction is located 14,000 feet from the runway threshold as shown in figure 3-28. Determine the glide slope parameters which will provide the required clearance over the obstruction.

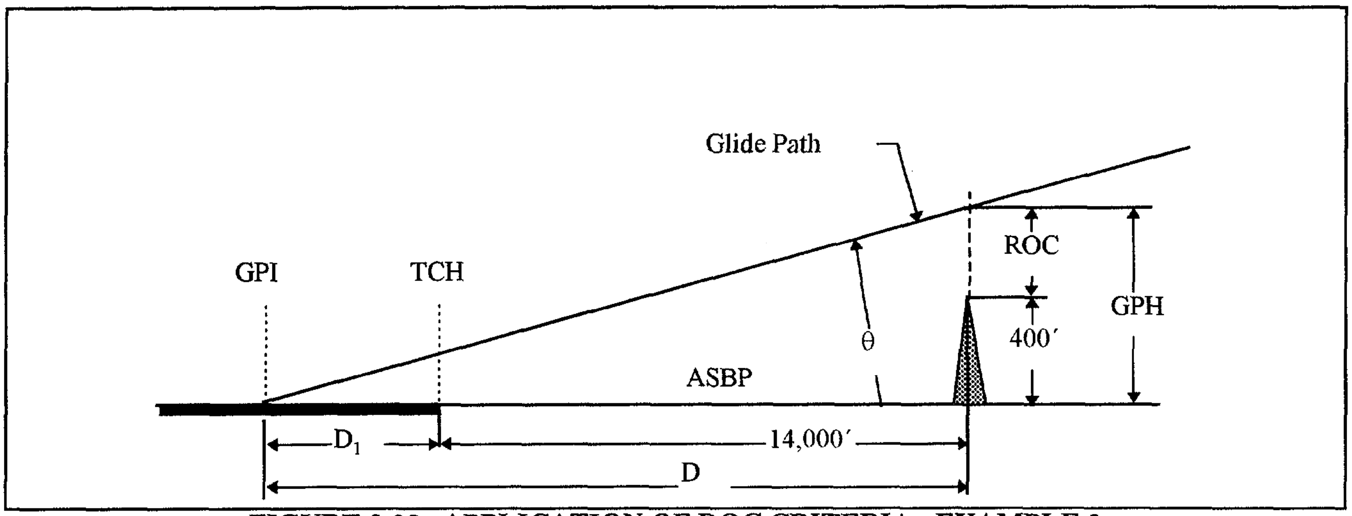


FIGURE 3-28. APPLICATION OF ROC CRITERIA - EXAMPLE 2

$D_{(t)}$ = 14,000 feet - 200 feet = 13,800 feet; therefore, ROC (Zone 3) is applicable.

$ROC_3 = .0187\ D + 75$ feet

$D = 14{,}000$ feet $+ D_1$

$ROC_3 = .0187\ (14{,}000 + D_1) + 75$ feet

Actual Obstruction Clearance = GPH - Obstruction Height
= D tan θ - Obstruction Height

Actual Obstruction Clearance = (14,000 feet + D_1) tan θ - 400 feet

Since the minimum actual clearance ≥ ROC_3:

$$(14{,}000 \text{ feet} + D_1) \tan\theta - 400 = .0187\ (14{,}000 \text{ feet} + D_1) + 75$$

Since D_1 and θ are implicit functions, it is necessary to assume a value for either and determine the corresponding value of the other:

Assume $D_1 = 1145$ feet ⇒ $\begin{cases} Tan\,\theta = \dfrac{737 + 21.4}{15{,}145} = .05 & \theta = \tan^{-1}(.05) = 2.87° \\ TCH = D_1 \tan\theta = 57.2 \textit{ feet} \end{cases}$

Assume $\theta = 3.0$ degrees $\Rightarrow$ $\begin{cases} .0524(14{,}000 + D_1) = 737 + .0187\,D_1 \\ .0337\,D_1 = 3.4 \qquad D_1 = 101\,feet \\ TCH = D_1 \tan\theta = 101 \times .0524 = 5.3\,feet \end{cases}$

It is obvious that, in this example, the combination of D_1 = 1145 feet and θ = 2.87 degrees will provide the most desirable facility The effect of the glide angle on the other operating parameters is again verified.

(3) Determine if the proposed glide path depicted in figure 3-29 will provide the ROC over the 25-foot obstruction located at a distance of 1500 feet from the threshold.

D = 1145 feet + 1500 feet = 2645 feet;
$D_{(t)}$ = 1500 feet - 200 feet = 1300 feet
At D = 2645 feet, ROC_1 criteria is applicable.

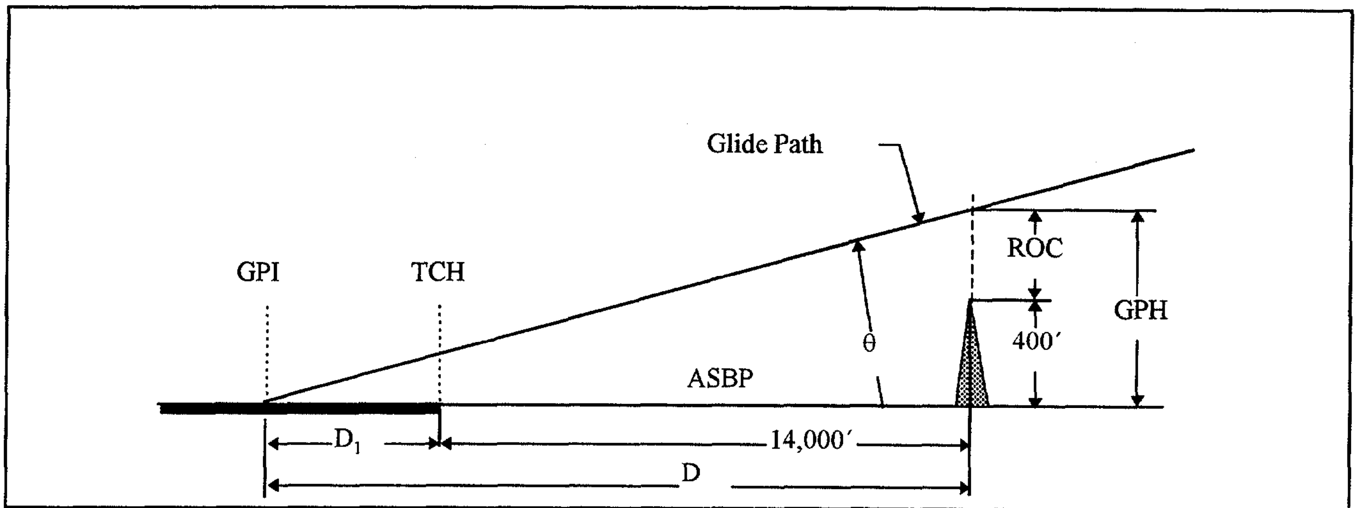


FIGURE 3-29. APPLICATION OF ROC CRITERIA - EXAMPLE 3

Required Obstruction Clearance

$$ROC_1 = D \tan\theta - \frac{D_{(t)}}{S_{(i)}}$$

$$= 2645 \text{ feet} \tan 3^\circ - \frac{1300\,feet}{34}$$

$$= 139 \text{ feet} - 38 \text{ feet}$$

ROC = 101 feet

Actual Obstruction Clearance

Actual Clearance = GPH - Obstruction Height

$$= 2645 \tan 3.0 - 25 \text{ feet}$$

$$= 139 \text{ feet} - 25 \text{ feet}$$

Actual Clearance = 114 feet

Since the proposed glide path's clearance over the obstruction is greater than the ROC, the tentative site and operating parameters are satisfactory.

38. SUMMARY. As indicated in the examples, it may sometimes be necessary, because of the interdependence of the various siting and operational parameters, to make several calculations for the optimum glide slope location and operational values. The calculations can be greatly reduced by initially assuming a value of 1100 feet to 1200 feet for D and noting that the greatest effect in raising the Glide Path Height (GPH) is obtained by changing the glide path angle. If it is not possible to comply with the ROC criteria within the permissible limits of the glide angle and TCH, then the following alternatives should be considered:

a. Removal of obstructions.

b. Displacement of runway threshold.

c. Establishment of landing minimums higher than desired.

d. Using a glide path greater than 3.0 degrees which requires an approved NCP.

e. Using a Wheel Crossing Height (WCH) higher than specified in Order 8260.34, Glide Slope Threshold Crossing Height Requirements which requires an approved NCP.

39. RESERVED.

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CHAPTER 4. MARKER BEACONS AND ANCILLARY AIDS

40. MARKER BEACONS.

a. General Information. The primary function of ILS markers is to designate specific points in the ILS approach path. To accomplish this, the markers radiate a highly directional vertical pattern at 75 MHz which has an elliptical shape in the horizontal plane. The marker antenna is oriented so that the ILS approach path passes through the minor axis of the pattern. Depending on the function of the marker, the detected modulation signal causes an instrument panel light of a particular color to flash, and/or a coded audible signal to sound as the aircraft passes through the radiation pattern, thus indicating a fix that can be used to determine the position of the aircraft on the ILS approach course.

b. Requirements. For category I operations, an outer marker or alternate final approach fix is required. For Category II/III operations, three markers are normally required: an outer marker, a middle marker, and an inner marker. The function, location, and characteristics of the markers are tabulated in figure 4-1. Since the inner marker of a Category II/III system is located within the approach light plane and a localizer antenna may be located within the approach light plane, the following limitations shall be observed: (Refer to the latest edition of Order 6850.2, Visual Guidance Lighting Systems for definitions and further discussion).

(1). Penetration of the approach light plane and or the approach surface plane (50:1) is prohibited for a Category II/III approach light system.

(2) Where necessary to ensure an acceptable level of performance, a localizer antenna array may penetrate the approach light plane of a category I approach light system; however, the antennas shall not obscure any light of the approach light system.

c. Location Tolerances. Since it is not always possible to physically locate the markers directly beneath the desired point in space, the following permissible variations have been established:

Outer Marker : ±800 feet both longitudinal and lateral.
Middle Marker : ±500 feet longitudinal and ±300 feet lateral.
Inner Marker : ±50 feet longitudinal and ±50 feet lateral.

NOTE: Longitudinal - along localizer course. Lateral - perpendicular to localizer course.

The markers should not be arbitrarily located within the tolerable limits; consideration must be given to the vertical shift in the marker/glide path intercept point which deviation from the nominal location will cause.

d. An alternate method of marking the glide path intercept point may at some localities be desirable and necessary. This will be the case if the intercept is more than 7 nautical miles from the end of the runway, or when a site within the prescribed limits is not available beneath the intersection. An alternate method of marking the intersection may be determined and approved by a regional office study.

e. If an alternate method of marking the glide path intercept is required, the outer marker shall be located either 4-1/2 nautical miles from the runway threshold on the localizer course line or where operational requirements for localizer-only operation will provide the lowest minimums (Office of Flight Standards will make this determination).

TYPE	FUNCTION	LOCATION	MODULATION FREQUENCY	CODE
Outer Marker	May mark Glide path procedure turn altitude or (MHA) intercept point.	4 to 7 nautical miles from threshold.	400 HZ	2 dashes/sec continuously
Middle Marker	May mark decision height point.	2000 to 6000 feet from threshold.	1300 HZ	Alternate dots and dashes at a rate of 95 combinations per min.
Inner Marker	May mark decision height point 100 feet above the highest elevation in the touchdown zone.	800 to 1500 feet from threshold.	3000 HZ	6 dots/second continuously.

NOTE: Markers shall be located within the limits specified in paragraph 40c.

FIGURE 4-1. ILS MARKER CHARACTERISTICS

Under no circumstances shall the outer marker be located so that an inbound aircraft flying at the minimum approach altitude intercepts the outer marker prior to intercepting the glide path.

f. Supplementary Requirements. The establishment requirements for markers used in conjunction with offset localizer and parallel ILS approaches are provided in the paragraphs concerning those ILS configurations. For a partial ILS (localizer only), an outer marker is generally established using the same criteria as for a full ILS.

g. Back Course Markers. To obtain the full operational benefits of the localizer, it may be desirable to establish position markers on the back course approach. Use standard ILS markers for the back course approach. The frequency of back course markers is 75 MHz. The standard ILS marker facility on the back course operates at the same power as the front course marker. Back course markers are identified by a tone of 3000 Hz keyed by a pair of dots at 95 per minute.

h. Marker Beacon Equipment.

(1) Formerly established marker beacons may use a pair of linear dipoles mounted 40 inches above a 20- by 20-foot counterpoise. The counterpoise is located either adjacent to the equipment shelter or above the shelter roof. The equipment shelter also houses the Compass Locator (COMLO) equipment, if installed. The collinear dipoles may continue operation indefinitely; however, when a relocation is required, the marker antenna will be replaced with a pole or tower mounted, stacked array, Yagi, or V-Yagi antenna.

(2) Pole Mounted Markers. ILS equipment may include a compact marker beacon system consisting of a vertical stacked array antenna and a small, solid state transmitter with a battery pack standby power source designed for mounting on a standard telephone pole. The pole mounted marker eliminates the need for a separate plot for the marker beacon; however, unlimited access to the marker pole shall be provided for maintenance purposes. At some locations peculiar siting problems (e.g., prevalent vandalism) may dictate the need for a marker plot. When required, a 6- by 6-foot fenced plot should be provided.

(3) Solid state markers housed in a walk-in shelter. Most solid state markers are housed in a transportable shelter. The size of the shelter is approximately 6 by 6 or 8 by 8 feet. A fenced 16- by 18-foot plot should be provided for these shelters.

i. Equipment Shelters. Refer to paragraph 21b of this order for shelter information. Figure 4-2 illustrates the siting criteria for a collocated marker and COMLO facility. The marker equipment will be installed in the shelter and the antenna will remain mounted on the pole or tower. Figure 4-4 depicts a typical plot layout for a collocated marker and COMLO facility with a mast antenna.

j. Obstruction Criteria. To function properly, the marker antenna shall be provided with obstruction-free zones. Figure 4-2 specifies the criteria for all marker beacon systems.

41. DISTANCE MEASURING EQUIPMENT (DME). Although the DME is not presently considered as an integral component of an ILS, it may be used in conjunction with the ILS. When so used, it is located at the localizer site. The DME may be used in lieu of the outer marker (OM)and if so, it shall be sited in accordance with paragraph 912 of Order 8260.3.B This is sometimes necessary where the ILS approach path is over water or where no site for the OM is available. The DME zero reference point shall be established at the DME site. A single DME may be used to serve back to back localizers on the same runway when all of the following criteria are met:

a. The DME is collocated with the localizer serving the primary runway,

b. Both localizers are on the same radio frequency,

c. The DME identification is interlocked to the radiating localizer, and

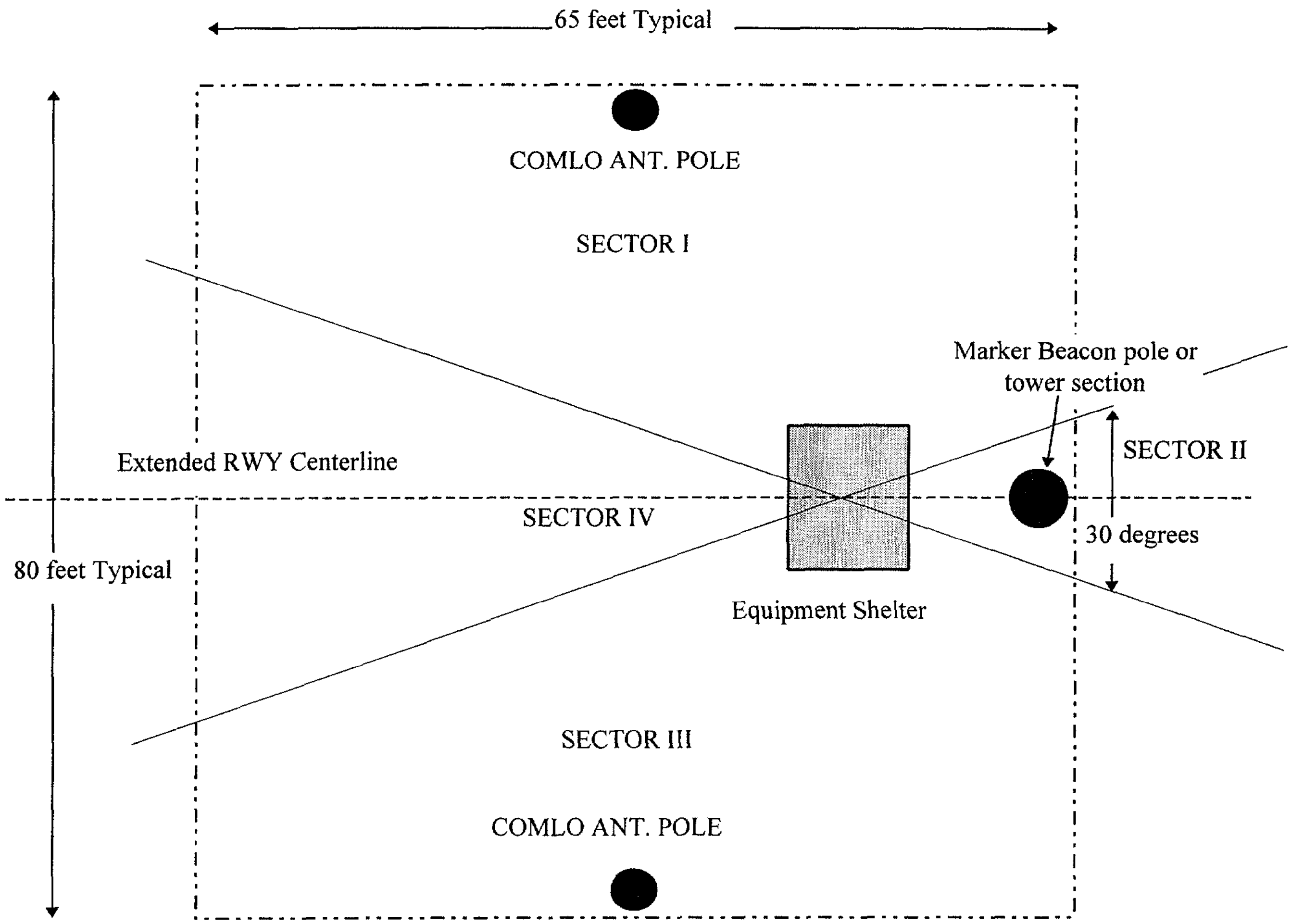
d. The DME will shutdown upon absence of localizer identification.

42. COMPASS LOCATORS.

a. If operationally required, non-directional compass locators may be installed at the middle marker and outer marker sites as an auxiliary aid to an ILS. These facilities are designated as locator outer marker (LOM) locator middle marker (LMM) respectively.

b. If the output power is 25 to 50 watts, the compass locator facility is designated with an MH indicating medium coverage. When over 50 watts is required to meet operational requirements, the facility is designated with an H indicating high coverage.

c. The compass locators transmit a 1020-Hz identification tone which modulates a two-letter Morse code signal. The code letters designate a particular ILS. The LOM is identified by the first two letters of the three-letter ILS identification and the LMM by the last two letters.



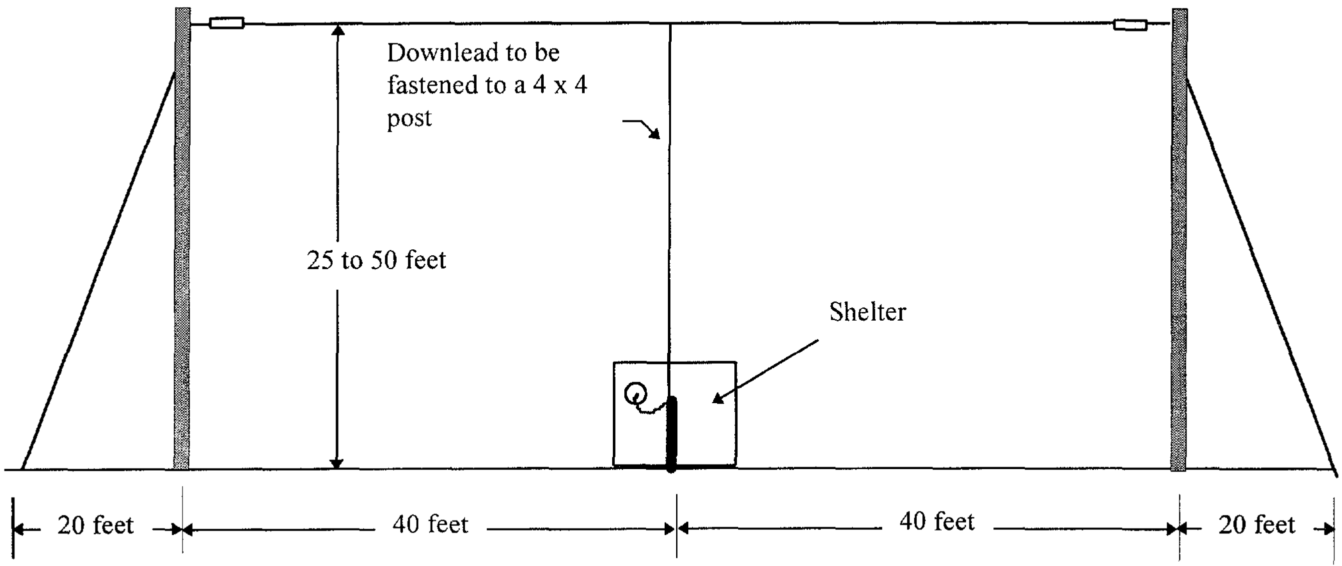
NOTES:

1. Sectors I and III are critical pattern forming areas for major axis coverage. Interference sources in these sectors within 100 feet of the antenna and protruding above a 20 degree angle with respect to the lower antenna element should be removed.

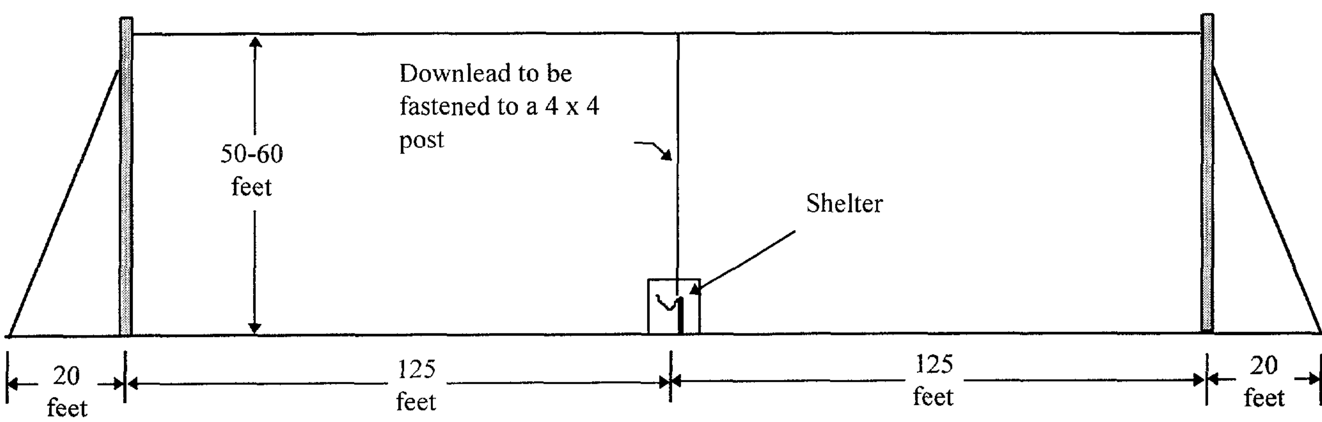
2. The designation COMLO shall apply only to those facilities where the output power does not exceed 25 watts. Higher power facilities shall be designated as MH (25 to 50W) or H (above 50W). At H locations, the depicted plot should be enlarged if it is necessary to increase the antenna pole spacing.

3. If a colocated COMLO is not used with the marker, the depicted plot size may be reduced.

FIGURE 4-2. SITING CRITERIA FOR COLLOCATED MARKER AND COMPASS LOCATOR



STANDARD ILS COMPASS LOCATOR



H-TYPE COMPASS LOCATOR

FIGURE 4-3. COMPASS LOCATOR ELEVATION AND PLOT SIZE REQUIREMENTS

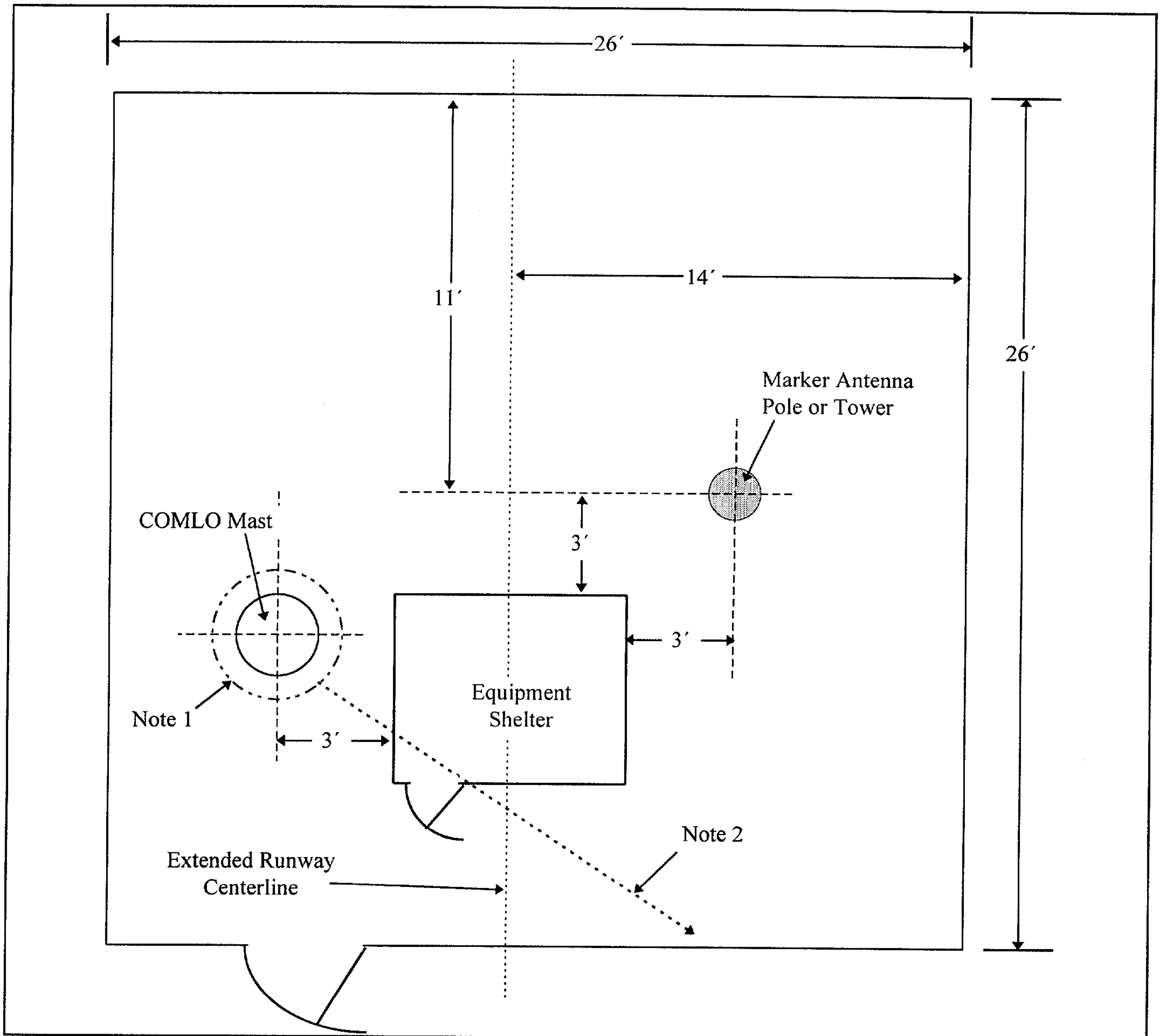


FIGURE 4-4. TYPICAL ILS MARKER WITH COLLOCATED COMLO AND MAST ANTENNA

Notes:

1. Ring buss shall be No. 2 AWG SD solid copper wire in a 3 foot diameter circle.

2. A minimum of sixteen equally spaced radials as long as or longer than the COMLO antenna height should be installed. Radials shall be buried from 2 to 6 inches below ground on the plot owned or leased by the FAA and a minimum of 6 inches below ground off the plot and shall be No. 6 AWG SD solid copper wire. See manufacturers instruction book for additional details.

d. The COMLO normally uses either a flattop antenna 25 to 50 feet high and 80 feet long, or a vertical "Top Hat" mast antenna. When a higher power facility (MH or H) is required, the antenna dimensions must be increased to 50 feet high and 250 feet long (see figure 4-3).

e. The COMLO equipment (and the marker equipment where collocated) are housed in an approximate 8- by 8- foot shelter, either permanent or transportable. A minimum plot size of 65 by 80 feet is required to accommodate the COMLO long wire antenna system (see figures 4-2 and 4-3). Some COMLOs are supplied with a vertical antenna and are collocated with the marker equipment, see figure 4-4. Refer to Order 6740.4. Non-directional Beacon (NDB) Installation Standards Handbook, for additional information.

43.-44. RESERVED.

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CHAPTER 5. MONITOR AND CONTROL REQUIREMENTS

45. GENERAL REQUIREMENTS.

a. Automatic Shutdown Feature. Local monitoring and control, including the capability to detect and shutdown the equipment in an alarm condition, shall be provided at all ILS facilities.

b. Remote Monitoring. When there is an air traffic control (ATC) facility, either a full or part-time tower or flight service station, a remote status indicator shall be provided for the localizer, the glide slope, and the COMLO facilities.

(1) If the status indicating location is a part-time facility, alternate ILS minimums will not be authorized during the period when the part time facility is not operational.

(2) Where there is no ATC facility, status monitoring of the ILS by the nearest ATC facility is required only if the ILS is to be designated for alternate minimums.

(3) Remote monitoring is not required for Category I marker facilities, however, remote monitoring is required for Category II/III marker facilities.

c. Remote Radio Monitoring. ILS and COMLO monitor receivers should be used for local ATC facility status indicators except when landlines are authorized as an operational requirement or justified on a relative cost basis.

d. Landline Monitoring. Monitoring via landlines may continue at existing Category I facilities that were monitored via landlines prior to the issuance of this order. Monitoring via landlines will be used at all Category II and III ILS facilities.

e. Control Lines. Control lines shall be installed only at new Category I localizer and glide slope facilities where positive ON/OFF control from the remote control point for dual-facing localizers is required or when two or more ILSs use a common frequency channel and at all Category II and III ILS facilities. Existing Category I facilities using control lines may continue to do so.

f. Localizer/Glide Slope Interlock. Interlock of the localizer and glide slope facilities solely to prevent the glide slope from radiating when the localizer shuts down is no longer required. The interlock should be removed at existing facilities and should not be installed at new or relocated facilities. At airports having facing ILSs with their localizers and glide slopes interlocked (refer to paragraph 13) to prevent simultaneous operation, failure of the operating localizer should not cause its companion glide slope to be shut down.

g. Remote Monitoring by Non-FAA Personnel.

(1) To help restore an ILS following an outage at locations without a local ATC facility and not authorized for alternate minimums, the assistance of a responsible person such as the airport manager or fixed based operator should be solicited. Permission should be obtained to locate the status indicating unit in their quarters, and request that the responsible maintenance office be alerted whenever an alarm occurs. It should be emphasized that no liability is attached and that the function is strictly for expeditious maintenance action.

(2) Designation of alternate minimums for an ILS without a local ATC facility will require initial and recurring costs for landlines. The requirement for alternate minimums at such locations should be carefully examined. Expenditure of funds shall be justified by a firm requirement for alternate minimums at the particular ILS.

46. EQUIPMENT REQUIREMENTS AND LOCATION.

a. Most remote control and monitoring equipment consists of an equipment rack located in the tower or Flight Service Station (FSS), equipment room, a remote control panel at each monitoring point, and an interphone unit and remote dialing panel at the primary monitor point which is usually the tower cab. Each unit is located at the optimum position in the area where it is used.

b. Mark I remote monitor (status indicating) equipment consists of localizer and glide slope receivers whose outputs will operate the respective facility status indicators located on a remote indicator panel. The remote indicator panel can also be used with landline status indicating equipment.

c. Category II and III Remote Indicator and Control Unit. The remote indicator and control unit is normally located in the tower equipment room. This unit contains a remote indicator panel with an interphone and remote control capabilities. Tied to this unit is the remote status display. This unit displays the status of the localizer, glide slope, far field monitor and markers, and it is normally located in the tower cab.

47. LANDLINE REQUIREMENT.

a. Localizer. Some Mark I systems use landlines for monitoring, control and interphone if operationally necessary. If the localizer is interlocked with another localizer, an additional pair of landlines is required. All Category II and III localizers require landlines.

b. Glide Slope. Mark I systems will not require any landlines. All Category II and III glide slopes require landlines.

c. Markers and Marker/COMLO. When required, a single pair of landlines will suffice for monitoring both facilities in addition to providing remote control over the COMLO. Landlines are required for control and monitoring of all Category II and III markers.

d. Landlines to the individual sites may be FAA-furnished lines, commercial lines, local airport authority lines, or a combination of the three. FAA cable is usually 12-pair cable except for Mark I systems where a 6-pair cable may be used. This cable may extend directly from the site demarcation terminal to the remote monitoring point, or it may be jumpered to the commercial or airport system at a nearby junction point; it is then jumpered back to the FAA system at the remote monitor point demarcation strip. The 12-pair cable provides sufficient spare circuits for future FAA use. No spare circuits are required on the non- FAA boundaries; the outer marker/COMLO will require commercial lines. The middle marker/COMLO may also require commercial lines depending on its location. Category II and III ILSs may require up to 25-pair cables between the facility and the control point.

48. RESERVED

CHAPTER 6. ILS POWER REQUIREMENTS

49. FACILITY REQUIREMENTS. All units of the ILS operate on single phase, 60 Hz power. The localizer, glide slope, and marker/COMLO each require 120/240 volt service. Pole mounted markers, marker only locations, and the remote control and monitoring equipment require 120V service.

50. SOURCES. Power to operate the ILS equipment is purchased from the commercial power company serving the airport area. Power to the localizer and glide slope sites will generally be furnished at the primary line voltage of 2400 volts. Step-down transformers are installed to obtain the proper operating voltages. To properly connect the transformers, obtain the primary voltage (phase to phase/phase to ground), the type of connection (delta or wye), and the electrical location of the power system ground. Power to the markers and marker/COMLO is usually provided at 120/240V, and a transformer is not required. The remote monitor and control equipment is operated on the control tower or FSS power circuit.

51. INSTALLATION REQUIREMENTS.

a. When the cable route is on airport property, power to the individual sites shall be underground. It is also desirable to use underground cable where the routing is adjacent to the airport property; this prevents the cable from becoming an obstruction hazard, signal reflection, or reradiation source. The cables for the marker/COMLO should be underground for a minimum distance of 250 feet from the building. The cables to the pole mounted marker may be routed overhead.

b. Transformers are to be located near the equipment building on the side opposite the antenna array. If standby power is used at the site, the transformer should be located near the standby power equipment.

52. STANDBY POWER.

a. Standby power will be provided in accordance with the latest edition of Order 6950.2, Electrical Power Policy Implementation at National Airspace System Facilities.

b. The ILS sub-systems are each provided with batteries for standby power operation. The batteries will operate the various sub-systems for a site specific period of time in the event of a power failure. The minimum period of time that any of the sub-systems will operate on battery power is four hours. The charge on the batteries is maintained during normal conditions by a charging circuit connected across the input power source.

53. CONTINUOUS POWER AIRPORT. A continuous power airport is an airport equipped with an emergency power source which maintains power for facilities on a selected runway, thus sustaining operations in visual flight rules (VFR) or instrument flight rules (IFR) conditions in the event of an area wide or catastrophic prime power failure. Continuous power airports are identified in the latest edition of Order 6030.20, Electrical Power Policy.

54.-56. RESERVED.

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CHAPTER 7. PROJECT ENGINEERING AND FACILITY ESTABLISHMENT

57. GENERAL PROCEDURE. When an ILS or one of its subsystems has been programmed for a particular location in accordance with the approved establishment criteria, the project engineering should commence. The project engineering should be conducted logically according to an established schedule based on the estimated commissioning date, equipment availability, etc.

58. PRELIMINARY SURVEY. The initial phase of the project engineering schedule is the compilation and study of all the necessary data and siting information. The preliminary survey should include:

a. Air Traffic Requirements. Existing flight operations and instrument approach procedures for the airport and other airports in the vicinity should be scrutinized. Items to be considered include: the procedure turn or minimum approach altitude, the availability of radar vectoring and/or other navigational aids which may be used in conjunction with the ILS, the desirable intersection of the glide path and approach altitude, the types of aircraft which will use the facility, and the desirable landing minimums.

b. Map and Data Analysis. Compile and study current airport maps, obstruction charts, topographic and obstruction data for the airport and surrounding area, and if available, a horizontal profile of the ILS approach zone.

c. Visual Survey. If the available information is not adequate to properly plan and site the ILS, a visual site survey by qualified engineering personnel shall be conducted. During the survey, approximate site locations should be determined, and terrain, obstructions, and possible sources of ILS signal degradation noted. When it is possible to locate the ILS facilities and minimize the effects of interference sources, the angular width, height, and position of these objects relative to potential sites should be determined by actual survey.

d. Liaison with Local Authorities. The airport manager or other local authority should be kept fully informed on the status of the ILS project. It will be necessary to confer regarding the location of the ILS units, marking of critical areas, removal of obstructions, etc. It should also be determined whether there are any plans for airport expansion or other major changes which may affect the operation of the ILS.

e. Real Property Planning and Acquisition. The real property acquisition office should be advised of tentative sites so that they may initiate preliminary negotiations with property owners for use of the land. Economic considerations may determine the location of off-airport sites and thereby affect the system's effectiveness.

59. PRELIMINARY REPORT.

a. When the information obtained in the preliminary survey has been carefully analyzed, a report summarizing the results of the survey shall be prepared by the project engineer. The report shall recommend the facility (e.g. , null- reference or capture effect glide slope) necessary to provide satisfactory operation, a summary of the expected performance of the facilities based on the presence of reflection sources and terrain conditions in the vicinity, and other problem areas or operational limitations which may affect the ILS establishment. The report should recommend site testing when it is not possible to predict the quality of a facility's performance.

b. The recommendations and projections of the preliminary report shall be studied by all concerned divisions (Flight Standards, Air Traffic, etc.). Since concurrence of these divisions is required, any nonconcurrence, objections, or reservations shall be resolved prior to continuation of the project. For example, if the report indicates that it would not be possible to attain the desired landing minimums (because of obstructions, terrain roughness, etc.), it may be necessary to compromise between the cost of improving the site and the extent to which such improvement will lower the minimums. Any changes to the preliminary report and its recommendations shall be incorporated into the report in the form of supplements or addenda.

c. The preliminary report shall include the analysis and recommendations regarding site acquisition in accordance with the latest edition of Order 4660.1, Real Property Handbook.

60. FINAL SURVEY. When concurrence has been obtained on the preliminary report and its supplements, the final project engineering may commence. This phase of the project includes:

a. Determining the exact location of the ILS facilities - localizer, glide slope, markers, etc.

b. Coordinating with the real property contracting officer to ensure that the FAA's access and use rights for permanent or long term (or short term as for site testing) have been established.

c. Scheduling the installation of any power cables and control lines to the site.

d. Coordinating special engineering to overcome peculiar siting conditions. This includes arranging for removal or repositioning of power lines or other potential interference sources.

e. Preparing instructions for the field installation engineer. This includes the localizer course width setting, glide slope angle setting, and special instructions and/or tests to overcome degrading site conditions.

61. SITE TESTING. Although site tests were formerly conducted at most localizer and all glide slope sites during the project engineering phase of an ILS establishment, it is no longer necessary to conduct site tests at all locations. Modeling of localizer and glide slope radiation patterns has evolved to the point where it is possible to predict the effect of various siting conditions on facility performance. By considering these effects during the engineering phase of the project, the need for site testing is significantly reduced. If the site analysis is thorough and accurate, it will only be necessary to adjust the operating facility to overcome slight differences resulting from intangible or non-measurable siting conditions. There will, of course, be locations where site testing may be advisable; for example, a highly congested area where interference sources make it impossible to predict facility performance. If site testing is required, it should be deferred until final grading and obstruction removal have been completed.

62. SUMMARY. Because of the wide variation in ILS siting conditions, it is not possible to provide specific instructions on how to overcome or offset the effects of each adverse condition. This order provides guidelines that must be used in conjunction with a thorough understanding of ILS facility operations to arrive at the optimum site and operating parameters.

APPENDIX 2. LOCALIZER SITE EFFECTS

1. DISCUSSION. The quality of an ILS localizer's course and clearance information is to a large extent determined by the operating environment of the system. Environmental factors which should be considered when siting a localizer facility include large buildings (such as hangers and terminal complexes), power lines, metallic fences, cylindrical structures (such as water towers and fuel tanks), and hilly or mountainous terrain.

2. THEORETICAL CONSIDERATION. Analysis of site effects on a localizer system's performance requires a thorough theoretical knowledge of the system. This information is available to those individuals that perform mathematical modeling of site effects on localizer (and glide slope) performance. When a difficult site is encountered, the site engineer is encouraged to seek mathematical modeling assistance through the Washington ILS Program Office. When a request for assistance is submitted, the program office will advise the site engineer of the topographical and other information that is required in order to perform the site analysis. The results of the mathematical modeling together with recommendations concerning the type of localizer antenna and the siting location will be provided to the site engineer.

3. IDENTIFICATION OF REFLECTION SOURCES. At most localizer sites the presence of an extensive number of buildings, hangars, fuel tanks, and other reflecting surfaces may require considerable analysis and flight testing to determine the exact interference source for a given area in space. Methods of conducting this analysis are provided here.

a. The effect which a reflected signal has on a localizer guidance information is depicted in figure 1. As the aircraft moves along the orbital flight path, its distance from the reflection source varies while its distance from the antenna array is, of course, constant. The composite signal at the aircraft, which is the vector sum of the direct and reflected signals, varies as the path length or relative phase of the reflected signal. A change in path length of one wavelength results in a single sine wave type variation in the composite signal. As the flight path proceeds through a sector encompassing several one wavelength incremental path changes, repeated sine wave variations will occur. This effect will also occur under the conditions depicted in figures 2 and 3 where both the direct and reflected signal path lengths are changing along the flight path but at a different rate.

b. At locations where scalloping is encountered, analysis of the flight inspection recordings and position information and application of one or more of the following equations (which are derived in figures 1, 2, and 3) may be used to determine the reflection source.

$$\textit{Orbital Flight:}\quad Sin\theta = \frac{\lambda}{s}$$

$$\textit{Radial Flight:}\quad Cos\theta = 1 - \frac{\lambda}{s}$$

$$\textit{Angular Flight:}\quad Cos\beta = Cos - \frac{\lambda}{s}$$

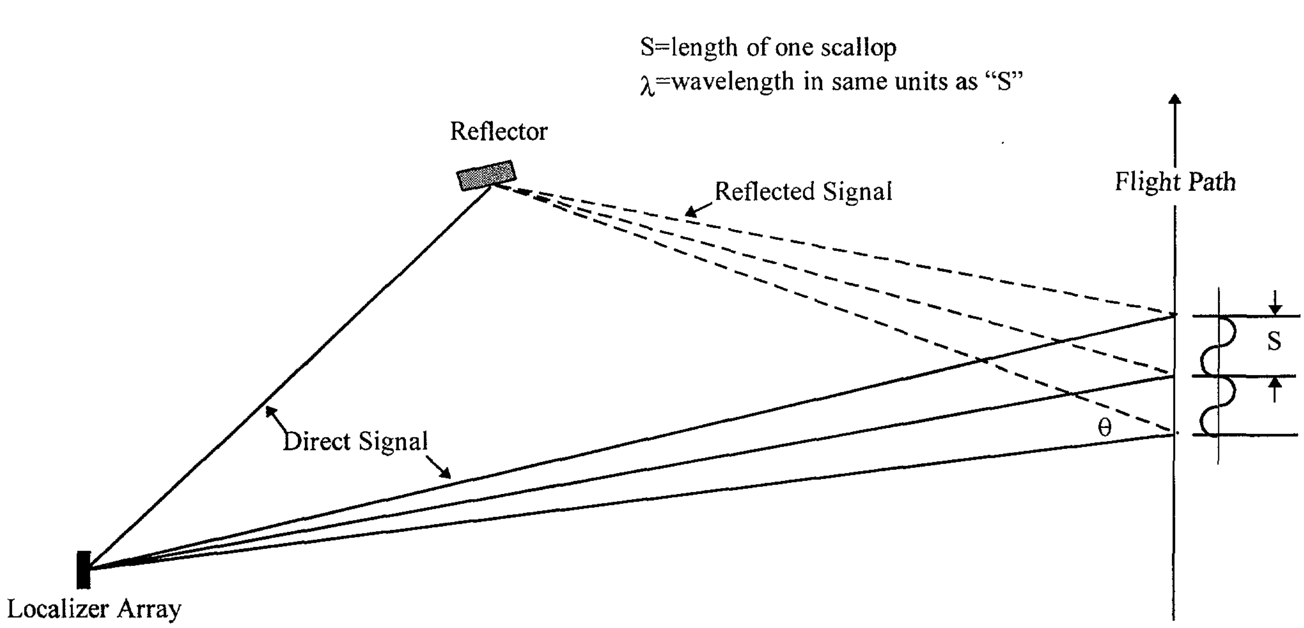
where θ = angle formed by direct lines from the measuring point to the antenna array and to the reflector.

s = length of one scallop.

λ = Wavelength at operating frequency in same units as s.

ϕ = angle formed by flight track and line from the flight track to the antenna array.

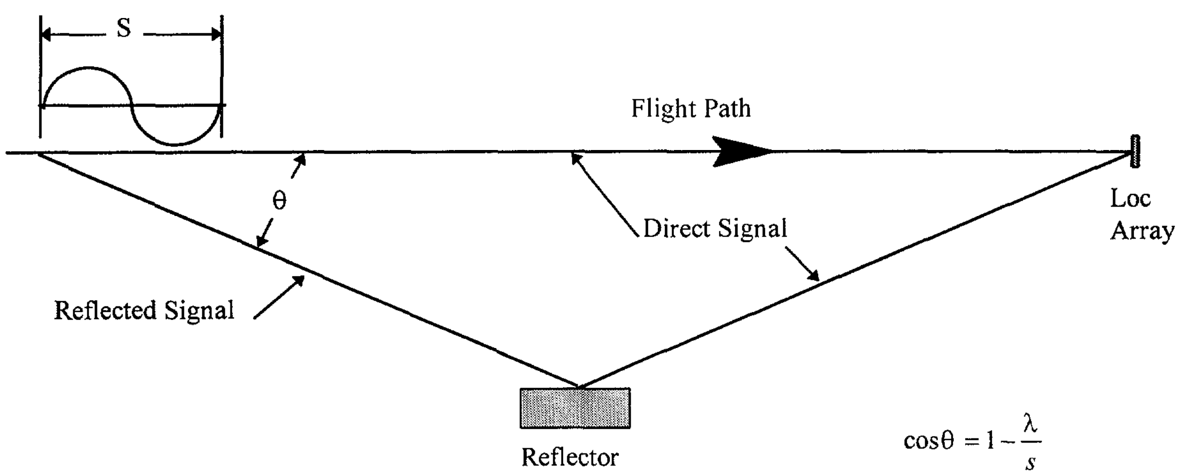
β = angle formed by flight track and line from the flight track to the reflector.



$$Sin\theta = \frac{\lambda}{s}$$

where θ *= angle formed by direct lines from flight path to reflector and array.*

FIGURE 1. SCALLOPING EFFECT - ORBITAL FLIGHT



$$\cos\theta = 1 - \frac{\lambda}{s}$$

FIGURE 2. SCALLOPING EFFECT - RADIAL FLIGHT

APPENDIX 1. GLOSSARY

ALS - Approach Lighting System

ARDH – Achieved Reference Datum Height

ASBL - Approach Surface Base Line

ASBP - Approach Surface Base Plane

ATC - Air Traffic Control

ATCT - Airport Traffic Control Tower

COMLO - Compass Locator

DDM - Difference in Depth of Modulation

DHP - Decision Height Point.

DME - Distance Measuring Equipment

FAA - Federal Aviation Administration

FSS – Flight Service Station

GPH – Glide Path Height

GPI - Ground Point of Intercept

GS - Glide Slope

IFR - Instrument Flight Rules

IM - Inner Marker

LDA - Localizer Directional Aid

LMM - Compass Locator at the Middle Marker site

LOC - Localizer

LOM - Compass Locator at the Outer Marker site

LPD - Log-Periodic Dipole

MM - Middle Marker

NCP - National Airspace System Change Proposal

NOTAM - Notice to Airmen

OFZ - Obstacle-Free Zone

OM - Outer Marker

RDH - Reference Datum Height

ROC - Required Obstruction Clearance

RPI - Runway Point of Intercept

RVR - Runway Visual Range

TCH - Threshold Crossing Height

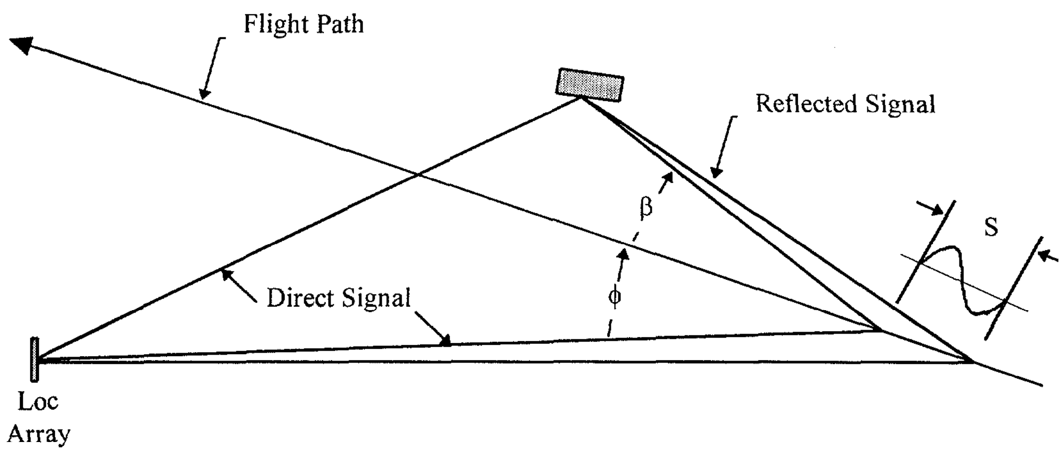
TERPS - United States Standard for Terminal Instrument Procedures (Order 8260.3)

TVOR - Terminal VHF Omnidirectional Range

TWA - Traveling Wave Antenna

VFR - Visual Flight Rules

WCH - Wheel Crossing Height



$$\cos\beta = \cos\phi = \frac{\lambda}{s}$$

where ϕ *= angle formed by flight path and line from flight path to array.*

β *= angle formed by flight path and line from flight path to reflector.*

FIGURE 3. <u>SCALLOPING EFFECT - ANGULAR FLIGHT</u>

Applications for these equations are illustrated by the following examples:

(1) At a localizer facility depicted in figure 4, severe scalloping was encountered along the course line beginning inside the outer marker and continuing inside the runway threshold. Analysis of the flight recordings, including highly sensitive Automatic Gain Control (AGC) recordings made on special flight tracks, indicated that the interfering reflections were originating from a large water tower. Removal of the water tower eliminated the scalloping and resulted in an acceptable facility.

(2) Severe scalloping on the localizer approach was encountered at the facility depicted in figure 5. Analysis of the scalloping and siting conditions indicated two potential reflecting objects of unknown quantity at $\pm\theta$. To ascertain which object was the interference source, an orbital flight check was conducted as shown in figure 5.

(3) On an orbital flight check of the facility depicted in figure 6, low clearances were measured in a sector of the orbit. The low clearances appeared to be caused by signal reflections; however, because of the random nature of the reflections, the location of the reflection source was not readily identifiable. Additional orbital checks showed that the low clearances were caused by two reflecting sources, with the random deflections resulting from combined individual scalloping.

4. <u>REDUCTION OF INTERFERENCE EFFECTS</u>. When the interference producing reflector has been located and complete removal is not possible, corrective action must be taken to overcome the degrading effects.

a. <u>Replacement</u>. The most obvious solution is to replace the array with a more directive system. Where reflections are extreme, a capture effect system may be required.

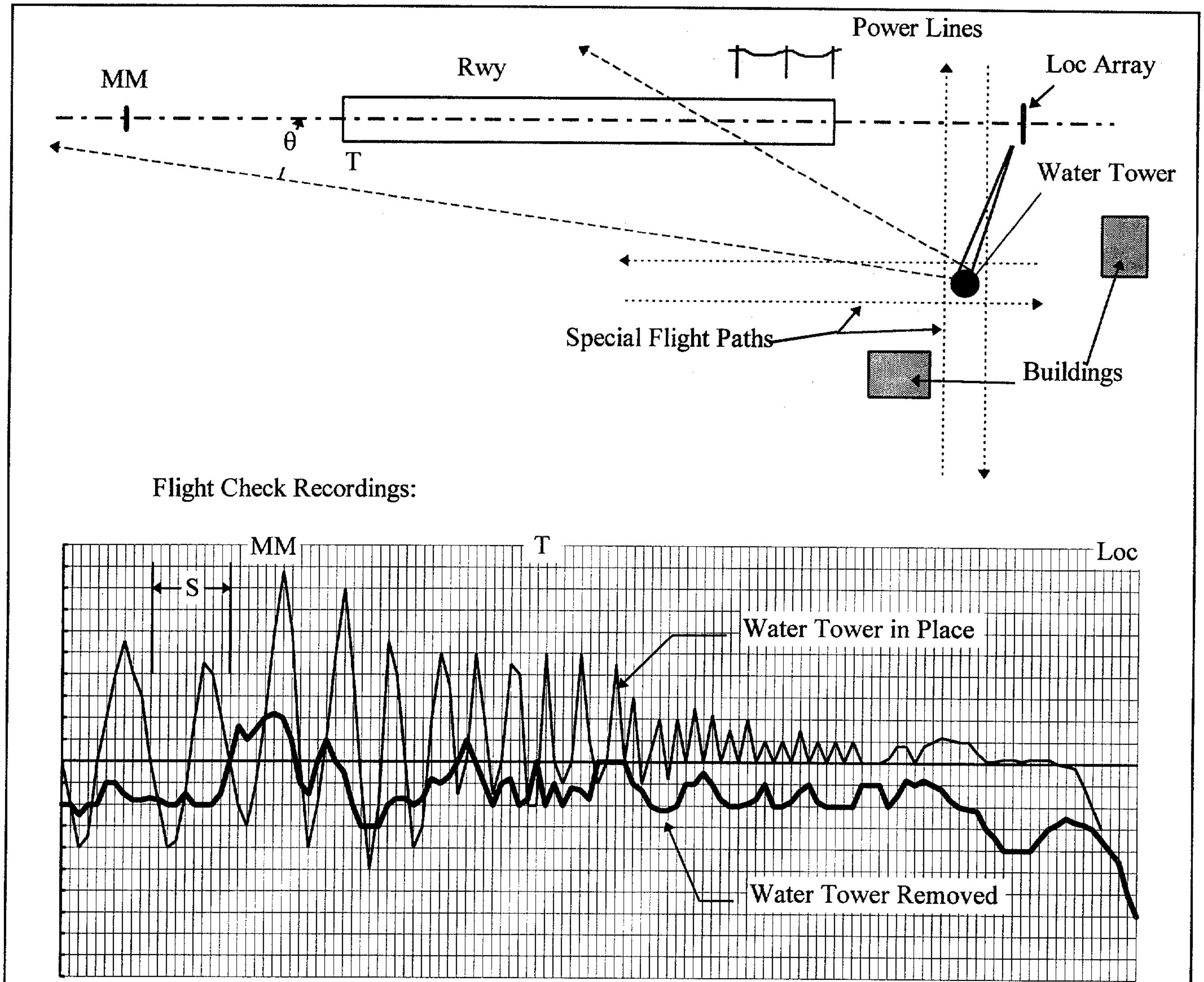
b. Signal cancellation techniques. One method of reducing interference is to use signal cancelling techniques at the reflector or secondary source.

NOTE: It is not feasible to attempt interference reduction control beyond the near field of either the primary or secondary sources.

(1) Field strength measurements in the vicinity of reflecting sources indicate the presence of very strong standing waves in space, with the VSWR decreasing as the distance toward the source is increased. By the introduction of a secondary reflector at a controlled distance in front of the primary reflector, the interference producing reflections from the latter can be cancelled or significantly reduced. The controlled reflector can be a single wire placed 90 degrees in front of the primary reflector. This space, S, is a function of the incident angle of the radiated signal as depicted in figure 7 and must reflect a signal 180 degrees out of phase with the primary reflected signal. Figure 8 depicts test results for reflections from a single wire.

$$S = \frac{\lambda}{4} \sin\theta$$

c. AC power lines are a common source of localizer signal reflections, particularly when they consist of several wires oriented in a vertical plane. The type of reflector lends itself to the application of the cancellation technique. Reorient the wires to the horizontal plane and space the individual wires so that reflected signals are self cancelling (see figure 9).



Normal Approach, Comparison of Water Tower in Place and Removed

FIGURE 4. ANALYSIS OF SCALLOPING - EXAMPLE 1

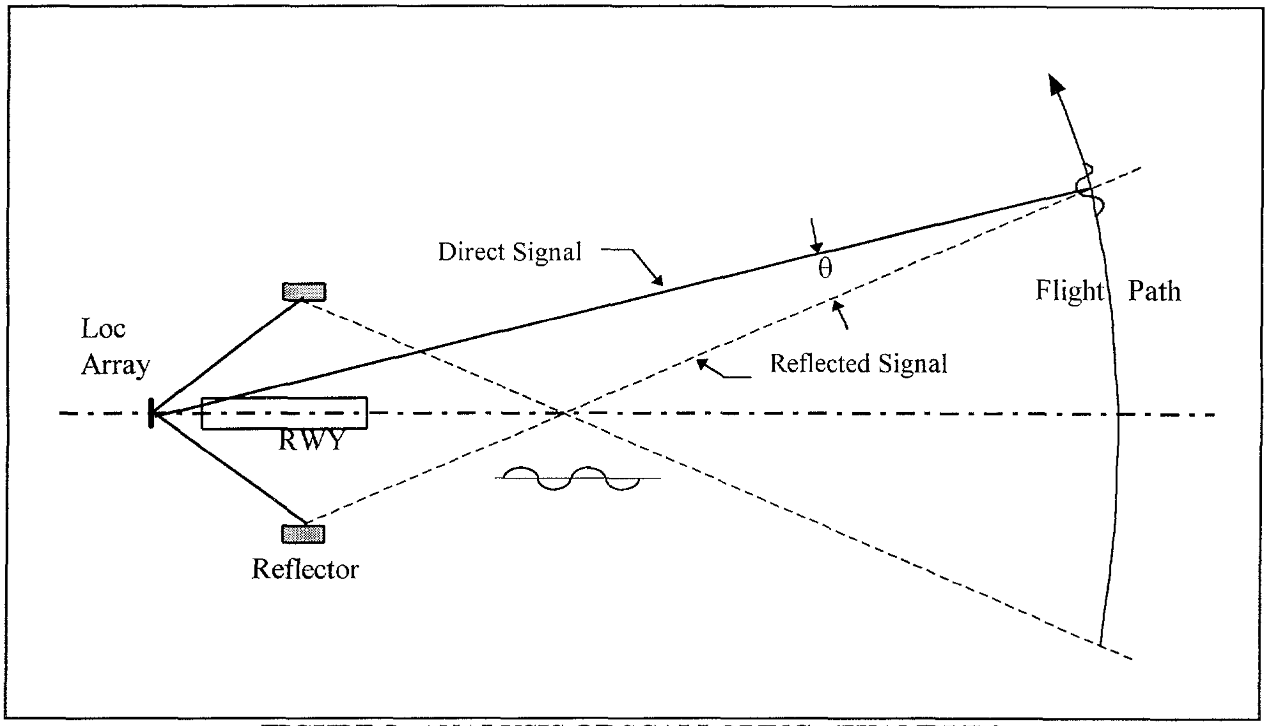


FIGURE 5. ANALYSIS OF SCALLOPING - EXAMPLE 2

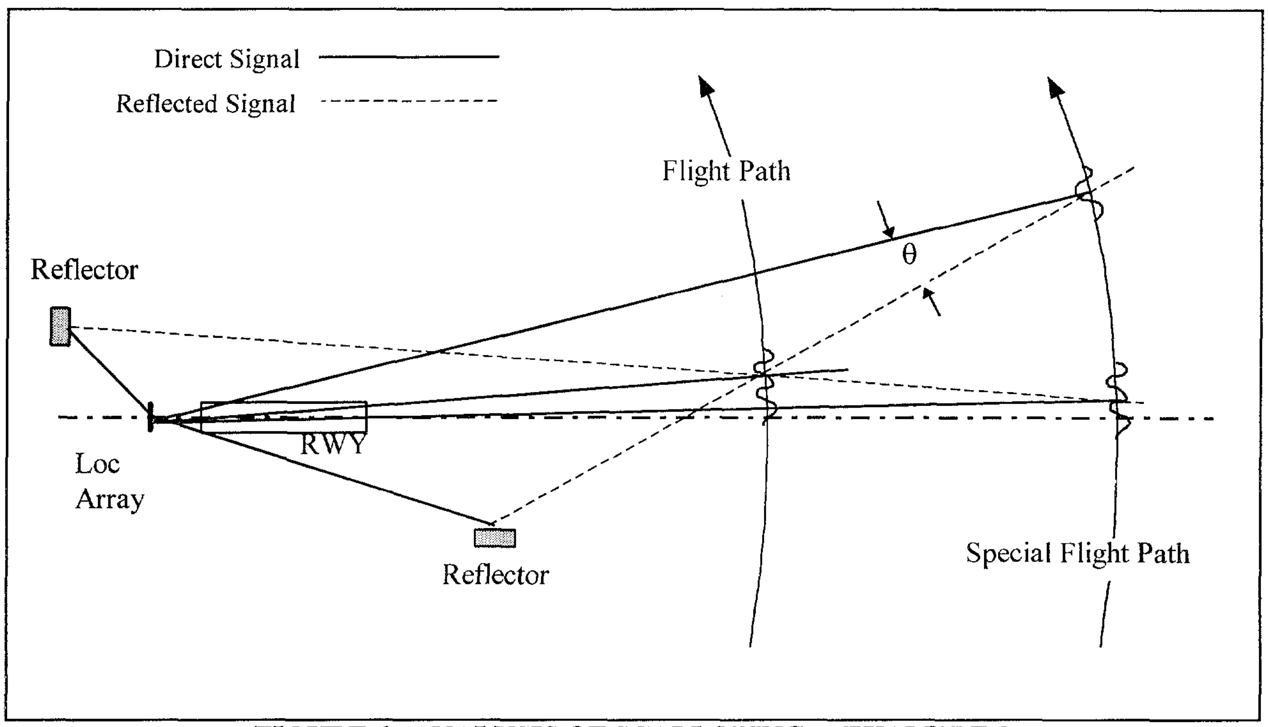


FIGURE 6. ANALYSIS OF SCALLOPING -. EXAMPLE 3

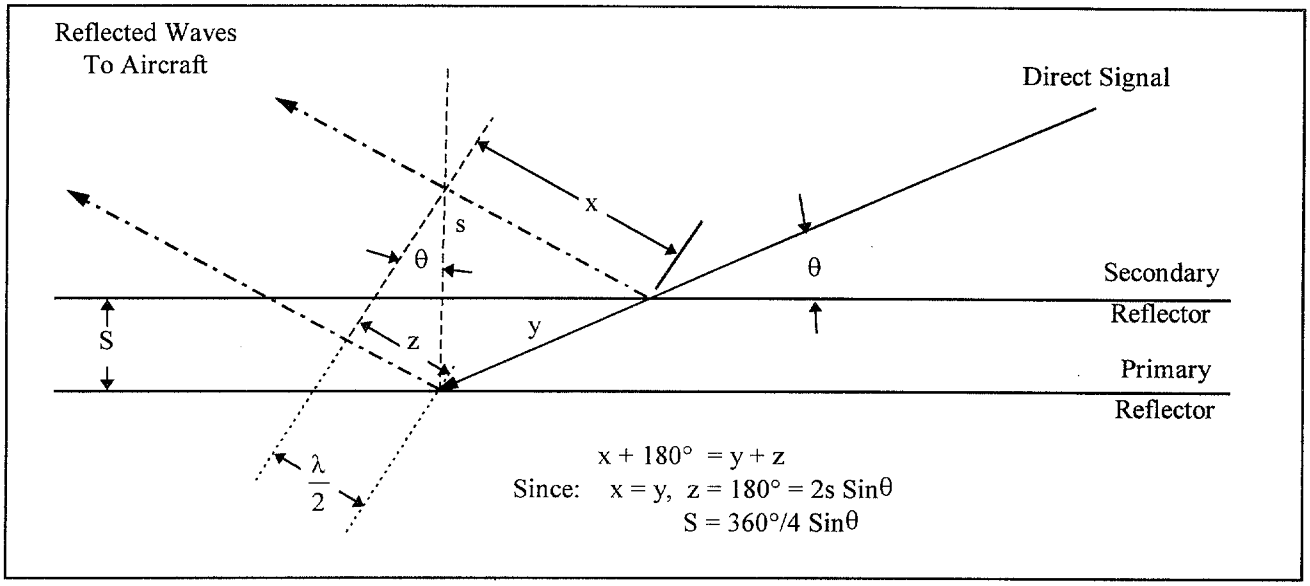


FIGURE 7. SIGNAL CANCELLATION CONCEPT

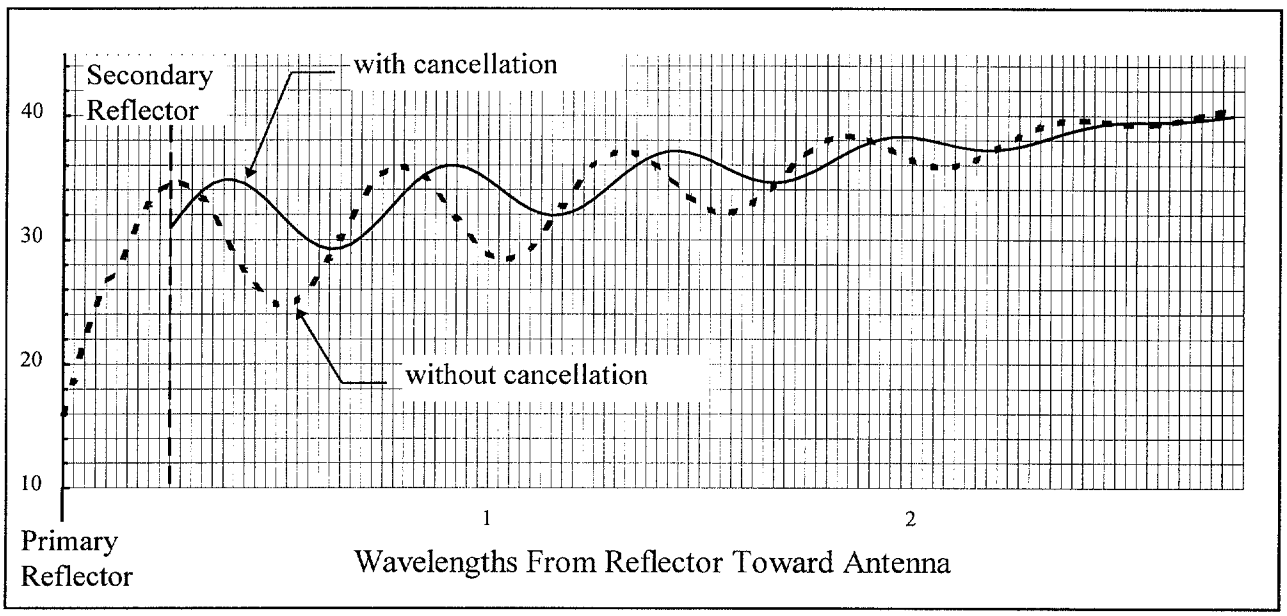


FIGURE 8. EFFECT OF A CANCELLATION WIRE ON A REFLECTED SIGNAL

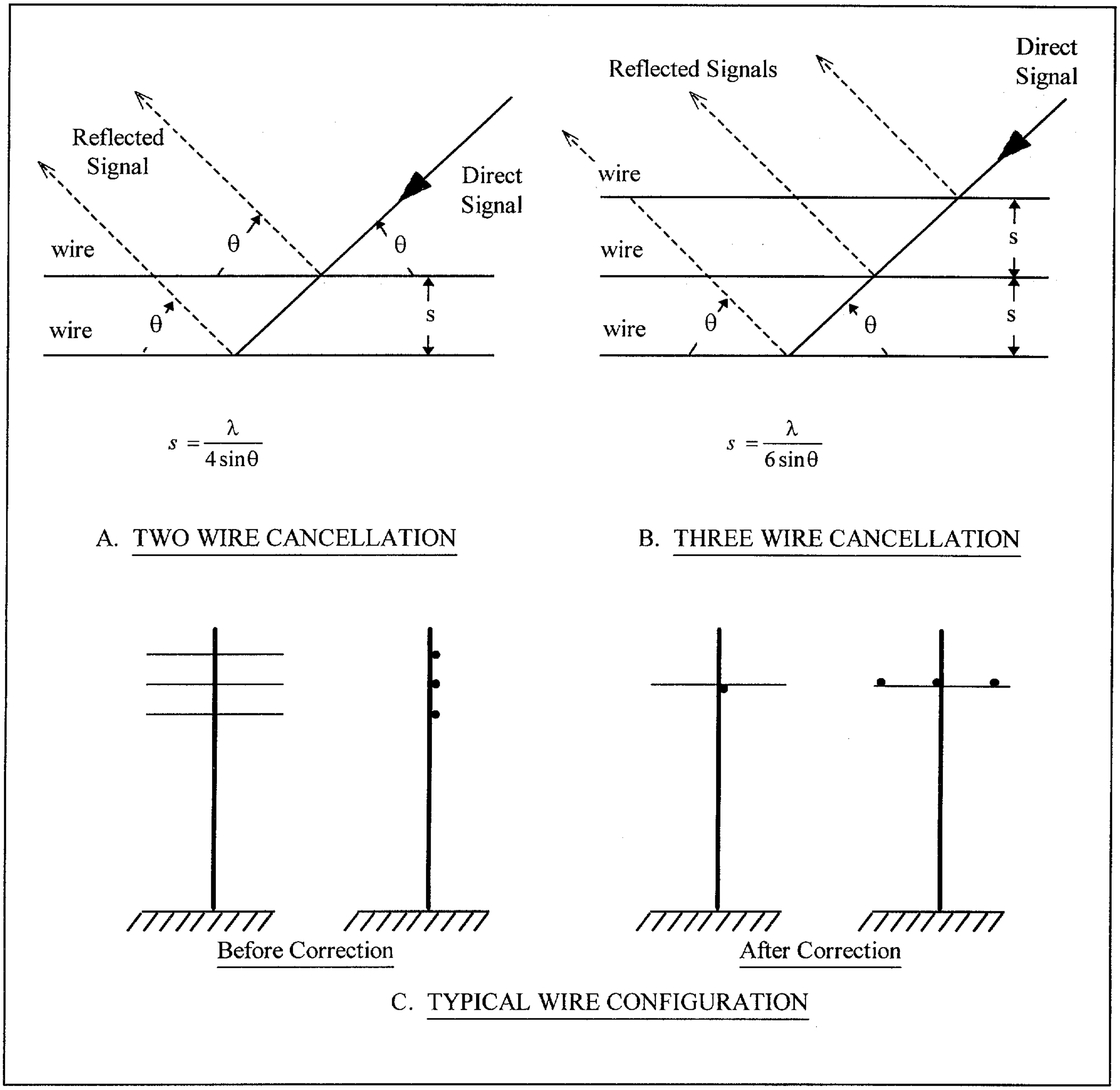


FIGURE 9. AC POWER LINE SIGNAL REFLECTION CANCELLATION

APPENDIX 3. GLIDE SLOPE SITE EFFECTS

1. **GROUND PLANE REFLECTIONS**. The size and location of the Fresnel zones for the ILS glide slope may be determined by the following formulas used in conjunction with figure 1. (Refer to Radiation Laboratory Series, Volume 13, "Propagation of Short Radio Waves, " and "Final Report on Site Reflections on ILS Glide Slope Facilities," October 1953, CAA Report No. 830-2, for a comprehensive Fresnel zone analysis.)

a. Fresnel zone longitudinal limits. The distance from the glide-slope facility to the points where the elliptical Fresnel zone on the approach terrain crosses the line of approach may be determined as follows:

$$Xo = \frac{D}{2}\left[\frac{1+\dfrac{2h_1(h_1+h_2)}{n\lambda D}}{1+\dfrac{(h_1+h_2)^2}{n\lambda D}}\right] \tag{1}$$

$h_1 = \dfrac{\lambda}{20}$ for a null-reference facility)

$h_2 = D\theta_p$ (where $\theta_p =$ elevation angle of aircraft)

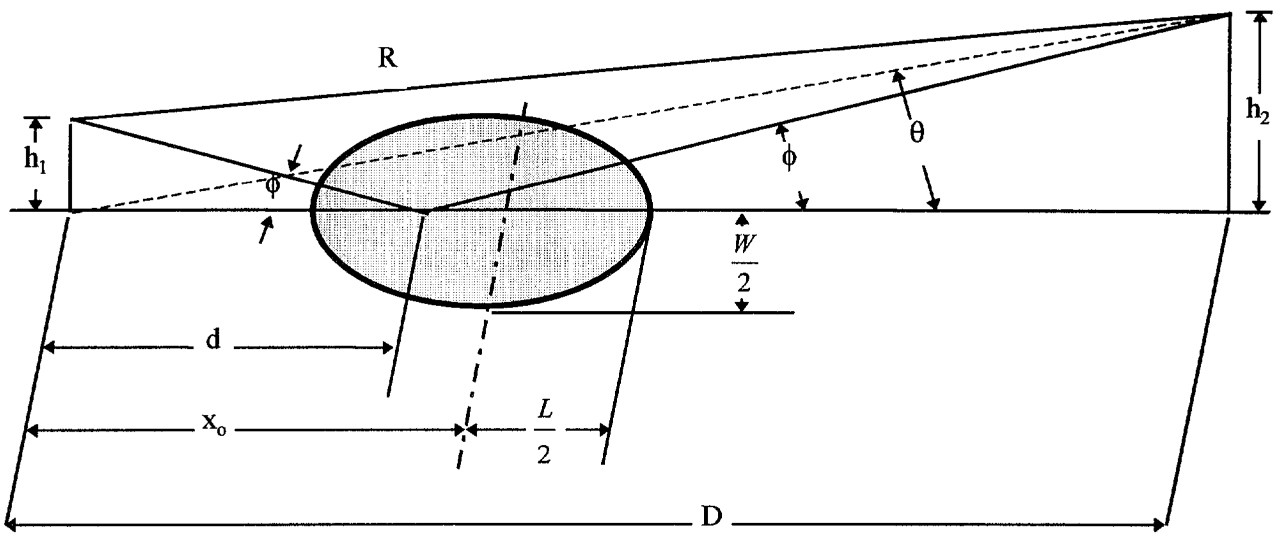
Substituting appropriate values and dropping negligible terms:

$$Xo = \frac{D}{2}\left[\frac{n+\dfrac{\theta_p}{\theta}}{n+\dfrac{\theta_p}{\theta}+\dfrac{D\theta_p^2}{\lambda}}\right]$$

(n = Fresnel zone number)

For an aircraft on the glide path ($\theta_p = \theta$) and the first Fresnel zone (n = 1) :

$$Xo = \frac{D}{2}\left[\frac{2}{2+\dfrac{D\theta^2}{\lambda}}\right] \tag{2}$$



h_1 - Height of glide slope antenna (upper).
h_2 - Height of aircraft.
D - Horizontal distance between glide slope antenna and aircraft.
R - Direct signal path from glide slope antenna to aircraft.
θ - Glide path angle.
ϕ - Ground reflected signal angle of incidence and reflection.
d - Horizontal distance from glide slope to geometric reflection point.
x_o - Horizontal distance from glide slope antenna to center of Fresnel zone.
L - Lenght of Fresnel zone.
W - Width of Fresnel zone.

FIGURE 1. FRESNEL ZONE FOR ILS GLIDE SLOPE

The near and far limits of the Fresnel zone may now be determined:

$$x = x_o \pm \frac{L}{2} \tag{3}$$

$$\frac{L}{2} = \frac{D}{2}\left[\frac{\sqrt{1+\frac{2}{n\lambda}\times\frac{2h_1h_2}{D}}}{1+\frac{(h_1+h_2)^2}{n\lambda D}}\right]$$

$$= \frac{D}{2}\left[\frac{\sqrt{n^2+2n}}{n+1+\frac{D\theta^2}{\lambda}}\right] \tag{4}$$

$$x_o \pm \frac{L}{2} = \frac{D}{2}\left[\frac{n+1\pm\sqrt{n^2+2n}}{n+1+\frac{D\theta^2}{\lambda}}\right]$$

For the first Fresnel zone (n = 1) and at the glide slope frequency ($\lambda = 2.96$ feet: $1/\lambda = .338$) :

$$x_o \pm \frac{L}{2} = \frac{D}{2}\left[\frac{2\pm\sqrt{3}}{2+.338D\theta^2}\right] \tag{5}$$

(with D expressed in feet and θ in radians)

From these formulas, the distance from the base of the glide slope antenna mast to the Fresnel zone center, and the near and far Fresnel zone limits, and the Fresnel zone length may be determined for any given glide path angle and aircraft position.

b. Fresnel zone lateral limits. The lateral limits of the Fresnel zone or the zone width at the minor axis may be determined by application of analytic geometry to the elliptical shaped zones. This yields the following equations:

$$\frac{W}{2} = \pm\frac{\sqrt{n\lambda D}}{2}\sqrt{\frac{1+2\frac{\frac{2h_1h_2}{D}}{n\lambda}}{1+\frac{(h_1+h_2)^2}{n\lambda D}}} \tag{6}$$

expanding and collecting terms:

$$\frac{W}{2} = \pm \frac{\sqrt{n\lambda D}}{2} \sqrt{\frac{n+2}{n+1+\frac{D\theta^2}{\lambda}}}$$

For the first Fresnel zone and glide slope frequency:

$$\frac{W}{2} = \pm \frac{\sqrt{2.96D}}{2} \sqrt{\frac{3}{2+.338D\theta^2}}$$

$$= \pm \frac{1}{2} \sqrt{\frac{8.88D}{2+.338D\theta^2}} \qquad (7)$$

$$= \pm \frac{1}{2} \sqrt{\frac{4.44}{\frac{1}{D}+.169\theta^2}}$$

And the total minor axis length:

$$W = \sqrt{\frac{4.44}{\frac{1}{D}+.169\theta^2}} \qquad (8)$$

c. Geometric reflection point. The distance from the glide slope antenna mast to the point of geometric reflection and the angle of reflection may be determined as follows:

$$\tan\theta = \frac{h_1}{d} = \frac{h^2}{D-d}$$

$$d = \frac{h_1 D}{h_1 + h_2} \qquad (9)$$

$$\tan\theta = \frac{h_1 + h_2}{D}$$

2. **CRITERION FOR TERRAIN ROUGHNESS**. Terrain irregularities have the effect of changing the path length and, thereby, the relative phase of the ground reflected signal. The amount of terrain roughness that can be tolerated is determined by the effect of the resulting phase shift on the aircraft cross pointer indicator.

$$\text{Tolerance for path deviations} = \pm 25\ \mu A.$$

$$= \pm .0292\ \text{DDM}.$$

a. To determine the terrain roughness which would result in an on-path deflection of $\pm 25\ \mu A$, it is assumed that the carrier signal is not affected by the irregularity and, except for the irregularity the ground plane, is an ideal mirror surface. For a null reference glide slope with a normal path angle of 2.5 degrees, the roughness criterion is determined as follows:

$$\text{DDM} = 2m\,(E_{ss}/E_{cs})$$

$$\pm .0292 = 2(.4)(E_{ss}/1.0)$$

$$E_{ss} = \pm .0365\ (90\ \text{Hz or } 150\ \text{Hz})$$

b. Hence, with E_{cs} assigned a value of $1\angle 0°$, the $25\mu A$ deflection is caused by a relative E_{ss} level of 0.0365. Referring to figure 2, the phase shift of the ground reflected signal which results in an on path E_{ss} level of this value can be determined. For the ideal glide path:

$$E_{ss} = I(\angle 0° - (R - H \sin\theta)) + I(\angle 180° - (R + H \sin\theta))$$

$$= 2I \sin(H \sin\theta)$$

$$= 0 \ @\ H = 4120°,\ \theta = 2.5°$$

Where terrain roughness occurs:

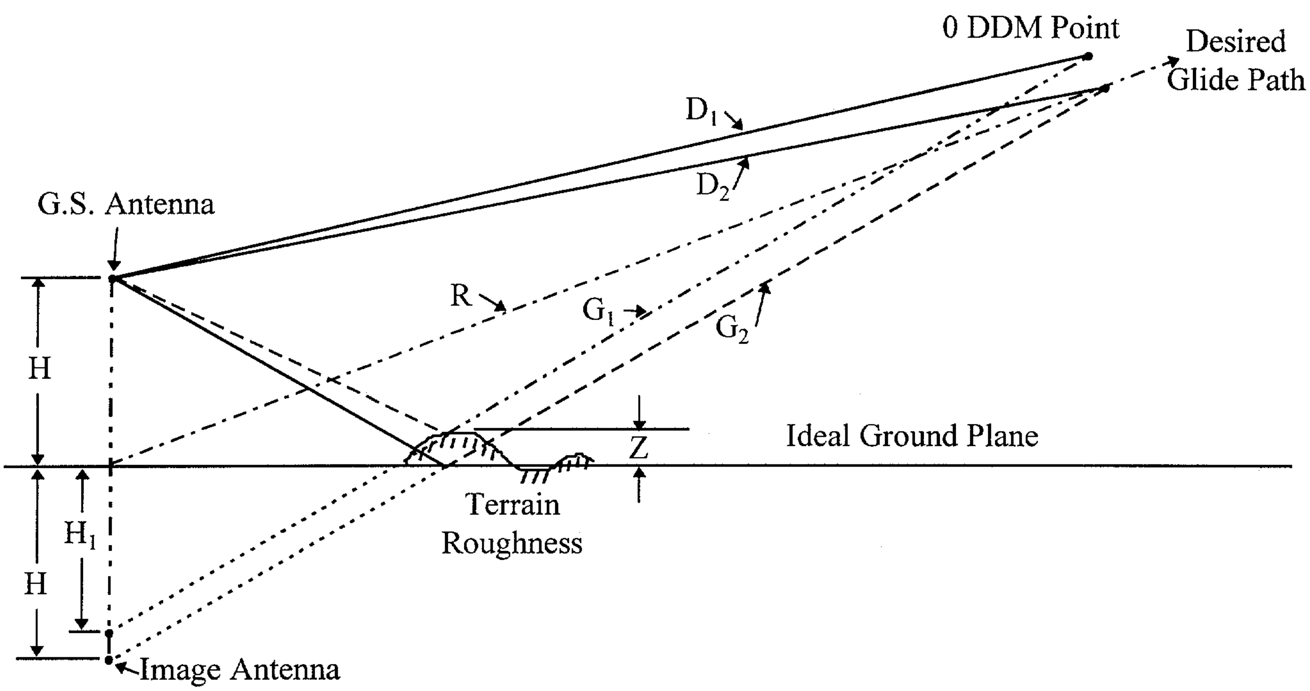
$$E_{ss} = I\angle H \sin\theta + I(\angle 180°\ H_l \sin\theta)$$

$$= I\angle 4120 \sin 2.5° - I\angle -H_l \sin 2.5°$$

$$= I\angle 180° - I\angle -0.0436 H_l$$

$$= 0 - I \sin(-0.0436 H_l)$$

(The cosine or quadrature terms dropping out.)



R - distance to aircraft.
H - Height of glide slope antenna and ideal image antenna
H_1 - Height of actual image antenna.
D_1 - Direct signal path, Ideal.
D_2 - Direct signal path, Actual.
G_1 - Ground reflected signal path, Ideal.
G_2 - Ground reflected signal path, Actual.
Z - Height of terrain roughness.

FIGURE 2. EFFECT OF ROUGH TERRAIN ON GLIDE PATH

c. Since I. = 0.255, relative value, for a normal path width of 1.4 degrees:

$$E_{ss} = I \sin(.0436H_1)$$

$$\pm 0.0365 = .255 \sin(.0436H_1)$$

$$\pm 0.143 = \sin(.0436H_1)$$

$$0.0436H = 171.7°/188..3°$$

$$= 180 \pm 8.3 \text{ degrees}$$

Since the term $0.0436H_1$ represents the equivalent electrical path length and normally equals 180 degrees (H_1 - H), the maximum permissible path length differential resulting from terrain roughness is 8.3 degrees.

d. Referring to figure 3, the terrain roughness criterion for a 2.5 degree path angle that causes an 8.3 degree change in the ground-reflected signals path length can be determined:

Permissible path length differential = 8.3 degrees

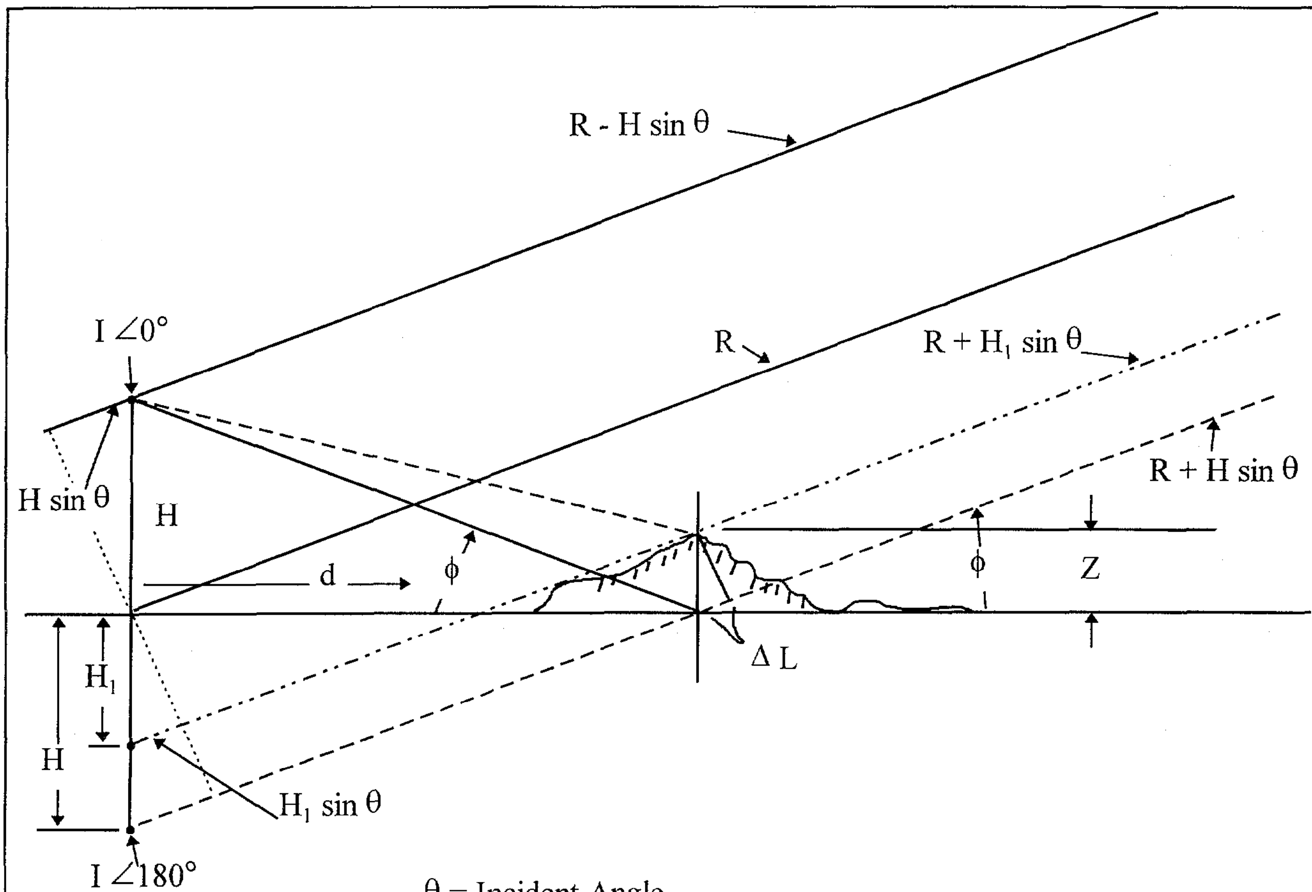
Path length differential = $2 \Delta L$

$$2\Delta L = 2 Z H/d$$

$$8.3° = 2Z(4120)/d$$

$$Z = .0010 d$$

Hence, the criterion for terrain roughness is a function of the distance of the roughness from the antenna. For a 2.5 degree glide angle, the roughness criterion is approximately 1 foot per 1000 feet from the antenna. For a glide angle of 3.0 degrees, the criterion is approximately 1.25 feet per 1000 feet.



θ = Incident Angle.
$\tan\theta = H/d$ $(=\sin\theta)$
d = Distance: Glide slope antenna to point of roughness.
ΔL = Incremental path length change.

FIGURE 3. TERRAIN ROUGHNESS CRITERION

APPENDIX 4. RDH/ARDH CONSIDERATIONS

1. **DISCUSSION**. When a site is nearly ideal, the reference datum heights (RDH/ARDH) will be nearly the same as the calculated TCH value. At sites where irregular terrain is present the reference datum heights will vary sometimes significantly from the ideal values. Longitudinal terrain slopes also will affect the RDH/ARDH. This appendix establishes criteria for determining what limits on terrain deviation may be allowed to exist and still have required tolerances for the reference datum heights met.

2. **IDEAL GROUND PLANE**. The values of reference datum heights for a null reference glide slope, operating over an ideal ground plane, with path angles of 2.8, 2.9, 3.0 and 3.1 degrees, are plotted versus antenna location in figures 1 through 4, respectively. These plots should be used as a first approximation in predicting if the chosen antenna location will produce the required RDH/ARDH. The effects of any irregular terrain on the RDH/ARDH must then be considered.

3. **UNIFORM TERRAIN GRADIENTS**. The effects of uniform terrain slopes on the RDH/ARDH are easily accounted for in siting a glide slope. The effects of uniform lateral and longitudinal slopes on RDH/ARDH are described below. Uniform slopes considered here are in the longitudinal and lateral directions.

a. Longitudinal slopes. A longitudinal slope results in an elevation difference between the runway threshold and the GPI. Assuming the antenna heights are properly chosen to provide the desired path angle with respect to the horizontal (see paragraph 27.g), the RDH/ARDH is given by the equation (see figure 5).

$$RDH = RDH_{(ideal)} - d \tan \alpha \qquad (1)$$

$$= RDH_{(ideal)} - e$$

where e is the threshold minus the GPI elevation.

b. Lateral slopes. The effects on RDH/ARDH caused by uniform terrain slopes in the lateral direction can be neglected for allowable gradients of 1.5 percent or less (see figure 3 through 9).

4. **IRREGULAR TERRAIN**. Types of irregular terrain considered here are simple elevated and depressed regions. Two-dimensional profiles of these types of irregular terrain are shown in figure 6. Plots of the response of RDH/ARDH to these types of non-ideal terrain are compiled in figures 7 and 8 for typical values of height (h), extent (w), and distance (y). These sensitivity curves are used to evaluate a potential glide slope site with respect to required RDH/ARDH tolerances.

a. Elevated terrain. Sensitivity curves for elevated regions of terrain are shown in figure 7 for heights of 2, 4, 6, 8, and 10 feet, and an extent of 10 feet. The region of elevated terrain greatly reduces the dependence of the path in space, and therefore of the reference datum heights, on the terrain that is farther from the antennas than the elevated region. For this reason figure 7 should be used to analyze the effects of elevated regions of terrain with an extent of 10 feet or greater.

b. Depressed terrain. Sensitivity curves for terrain depressions with depths of 2, 4, 6, 8, and 10 feet and extents of 100 and 200 feet are shown in figures 8 and 9. As the extent of depressed terrain increases, so does the change of RDH/ARDH from the ideal values.

c. Application notes. The sensitivity curves are compiled for a 3.0 degree path angle. For lower path angles, the reference datum heights depend on terrain that is farther from the antennas. This should be taken into account when analyzing a site using the sensitivity curves. In addition, the peak values of the sensitivity curves should be considered as a worst case for a given height (or depth) of irregular terrain, rather than interpolating a discrete value from the curves. This is because the period of oscillation of the sensitivity curves depends greatly on the shape of the region of irregular terrain, while the amplitude of the sensitivity curves is basically dependent on the height of the irregular terrain for elevations, and dependent on the extent for depressions.

Example 1.

Consider a site where a Category I installation is desired. To determine what limits on terrain deviation may be allowed and still have RDH tolerances met, the sensitivity plots are applied as follows:

1. Determine RDH/ARDH tolerances.

Since only Category I operation is required, no specification of ARDH is necessary. Assume for this particular site that Height Group 2 aircraft are expected to operate. FAA Order 8260.34, Glide Slope Threshold Crossing Height Requirements, prescribes limits of 35 feet to 65 feet for RDH, while the recommended RDH is 45 feet ± 5 feet. Assume the antenna location is chosen to provide a TCH of 45 feet. The tolerance limits on RDH are then 45 feet plus 20 feet and minus 10 feet.

2. Apply tolerance limits to sensitivity curves.

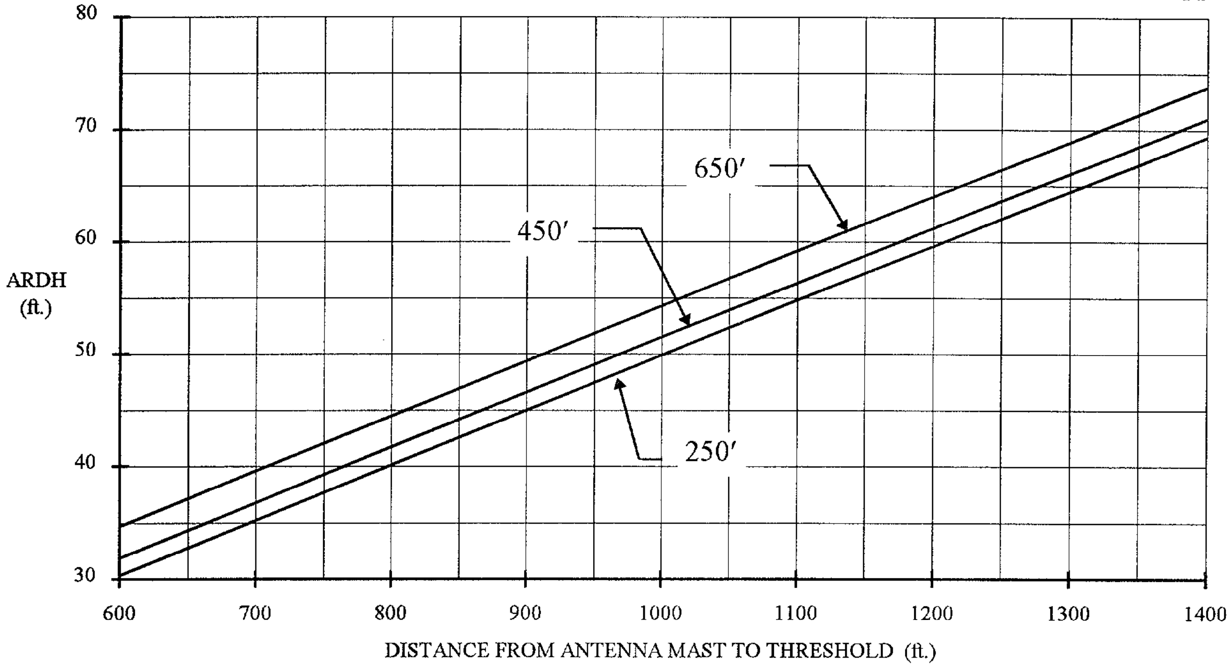
Applying the stricter of the tolerances for RDH (minus 10 feet) to figure 7 shows that the maximum height of elevated terrain that can be tolerated is slightly greater than 10 feet to a distance of approximately 2400 feet from the antennas, approximately 2400 feet from the antennas, and decreasing to less than 5 feet at 4000 feet from the antennas. Applying the same tolerance to figure 8 shows that regions of depressed terrain up to 500 feet in extent can be allowed.

3. Evaluate the site terrain with respect allowable values of terrain deviation.

A profile of the terrain at the site is shown in figure 10. The elevated terrain between 1000 feet and 3000 feet has a maximum roughness of 12 feet, which is outside the limits determined in step 2. This site, therefore, would not be a good location for a null reference glide slope.

Example 2.

Consider a glide slope site being proposed for Category II operation. FAA Order 8240.47, Determination of Instrument Landing System (ILS) Glidepath Angle, Reference Datum Heights, and Ground Point Intercept, prescribes tolerance limits of 55 ± 5 feet for RDH, while ARDH values must remain within ± 6 feet of the commissioned RDH or 55 ± 5 feet. To determine the allowable limits of terrain elevation the required tolerances are applied to figure 7. For the RDH tolerances of 55 ± 5 feet, the maximum elevation of irregular terrain is interpolated to be approximately ± 7 feet in the region from 1000 feet to 3000 feet from the antennas. Similarly, the limits on terrain deviation which allow the ARDH tolerance of 55 ± 5 feet to be met is seen to be approximately ± 10 feet in the region extending out to 2000 feet from the antenna mast.



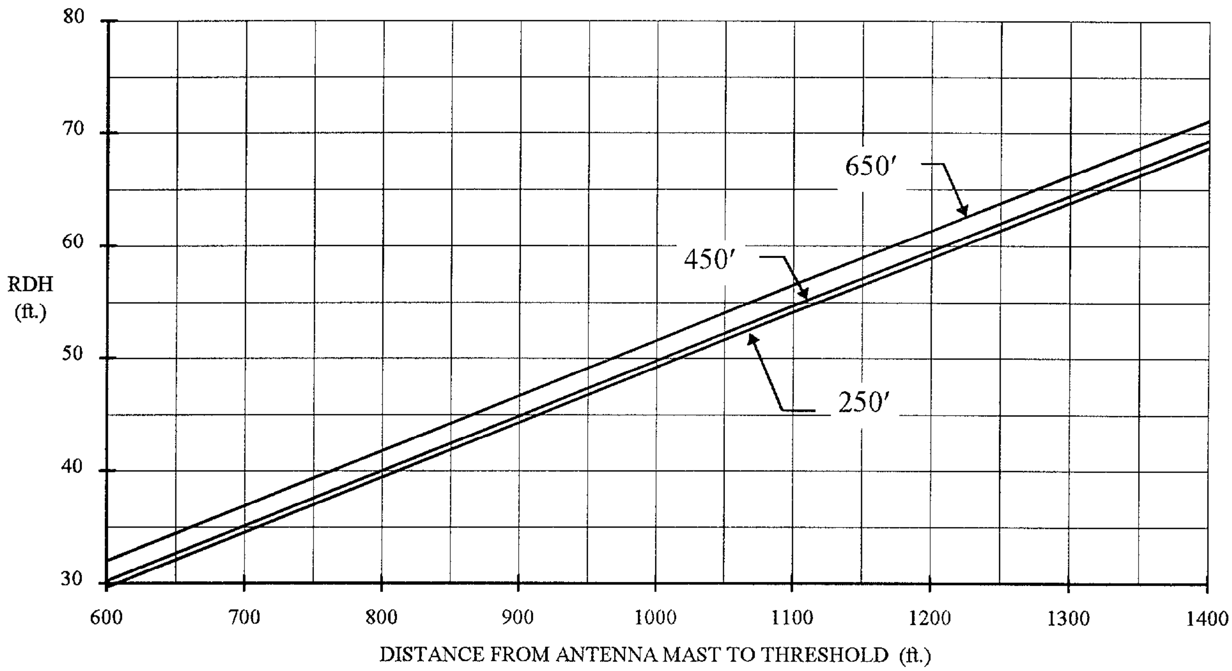
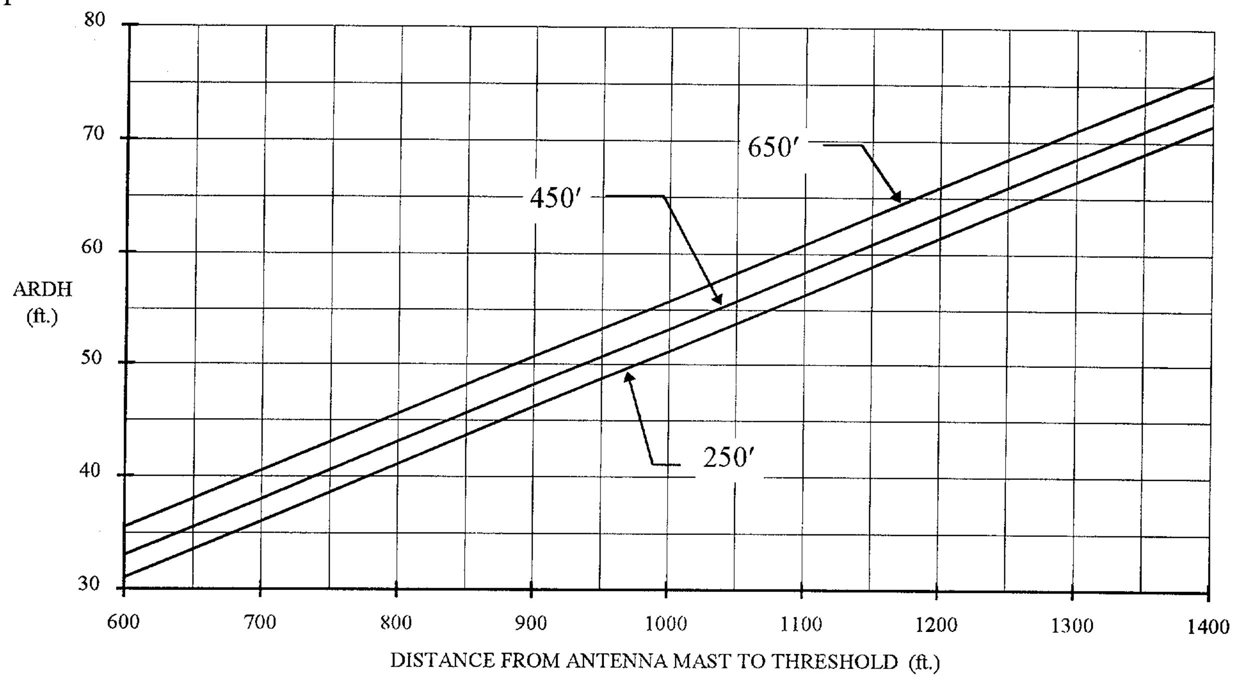


FIGURE 1. **RDH AND ARDH VERSUS DISTANCE FROM THE ANTENNA MAST TO THE THRESHOLD ALONG CENTERLINE, FOR DISTANCES OF THE ANTENNA MAST FROM CENTERLINE OF 250, 450, AND 650 FEET, AND FOR A PATH ANGLE OF 2.8 DEGREES.**



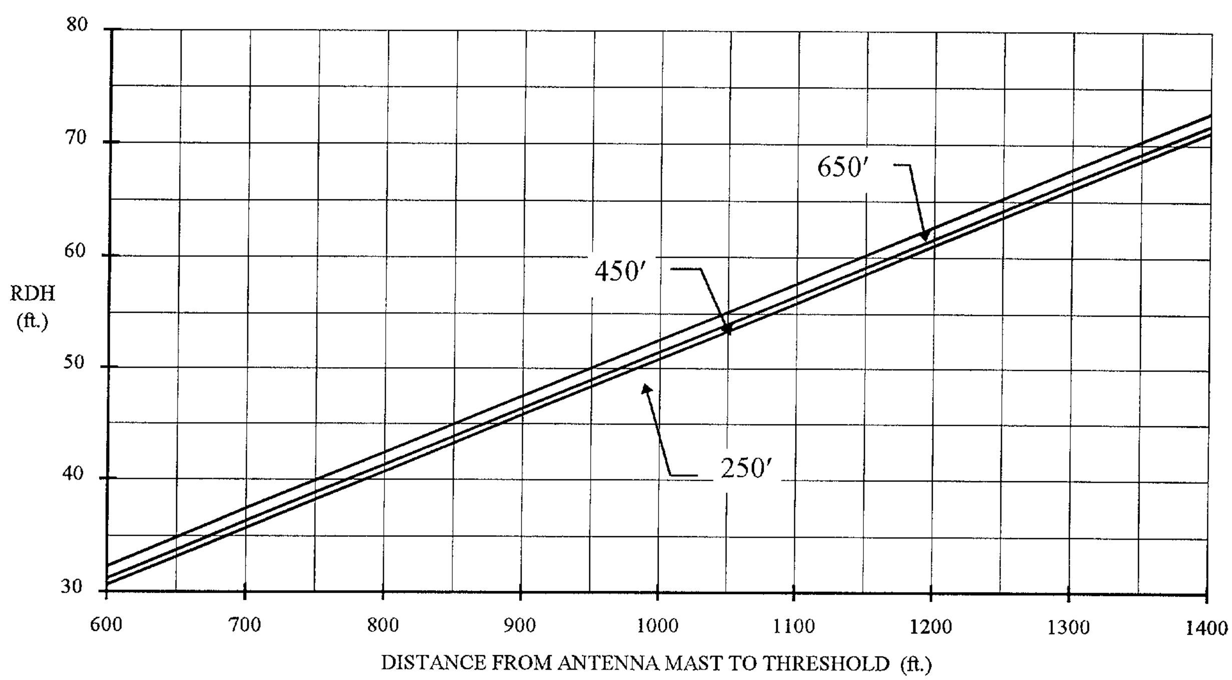
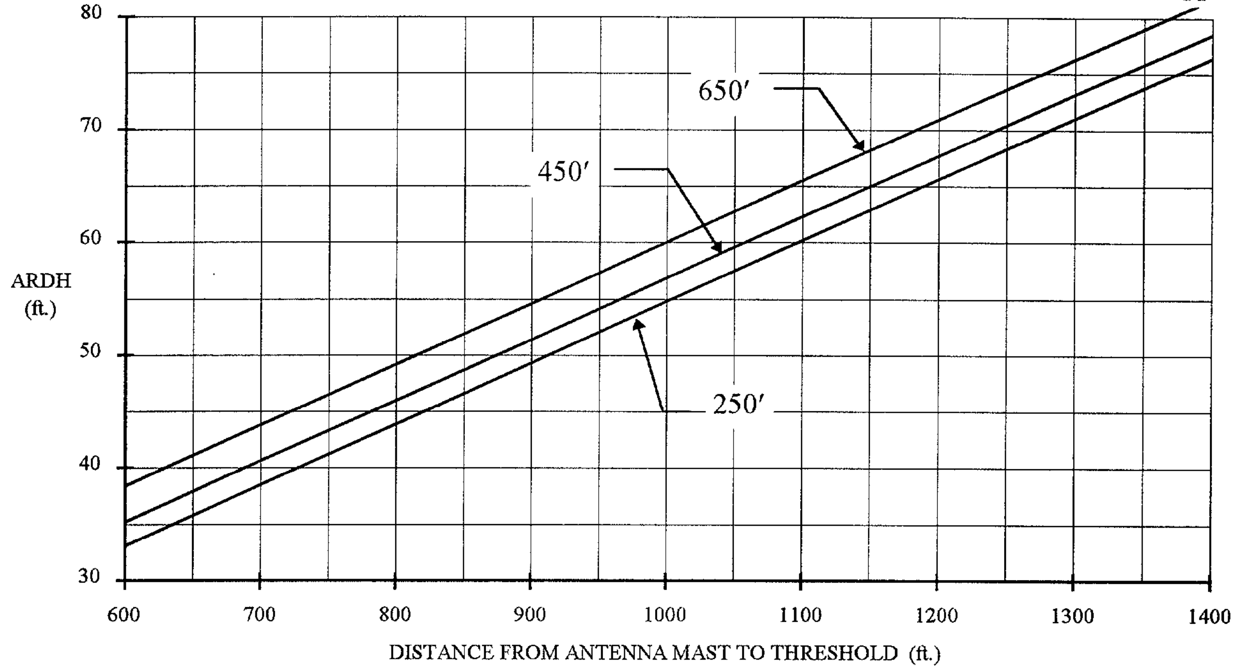


FIGURE 2. RDH AND ARDH VERSUS DISTANCE FROM THE ANTENNA MAST TO THE THRESHOLD ALONG CENTERLINE, FOR DISTANCES OF THE ANTENNA MAST FROM CENTERLINE OF 250, 450, AND 650 FEET, AND FOR A PATH ANGLE OF 2.9 DEGREES.



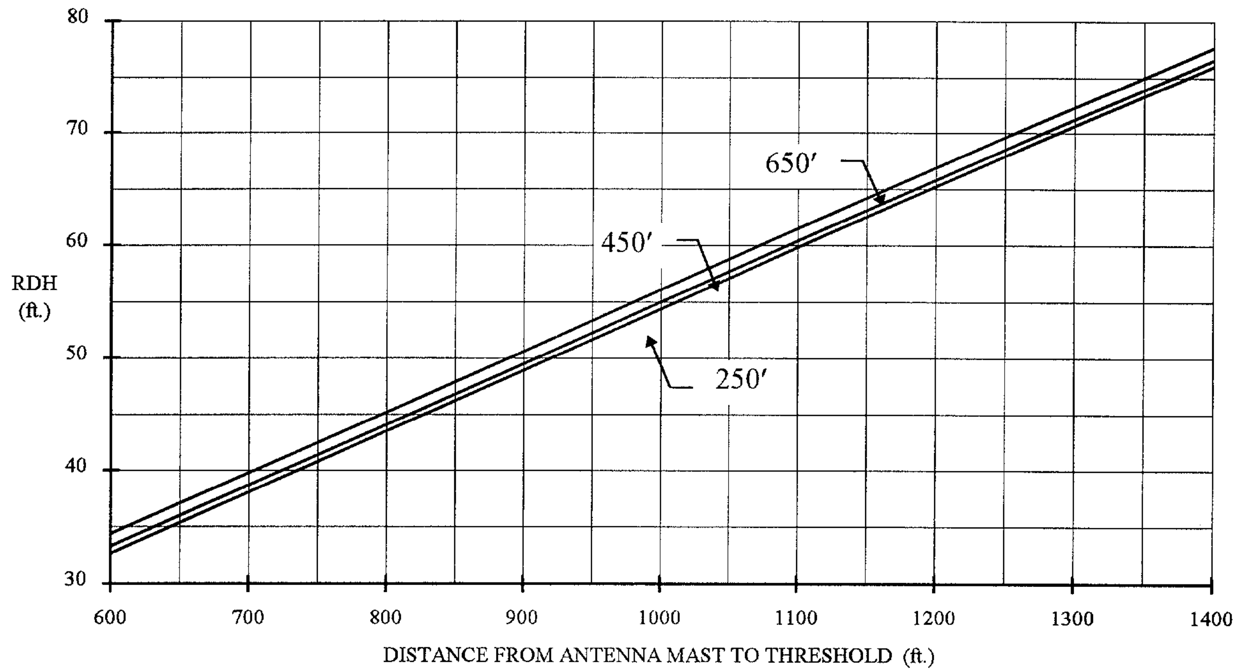
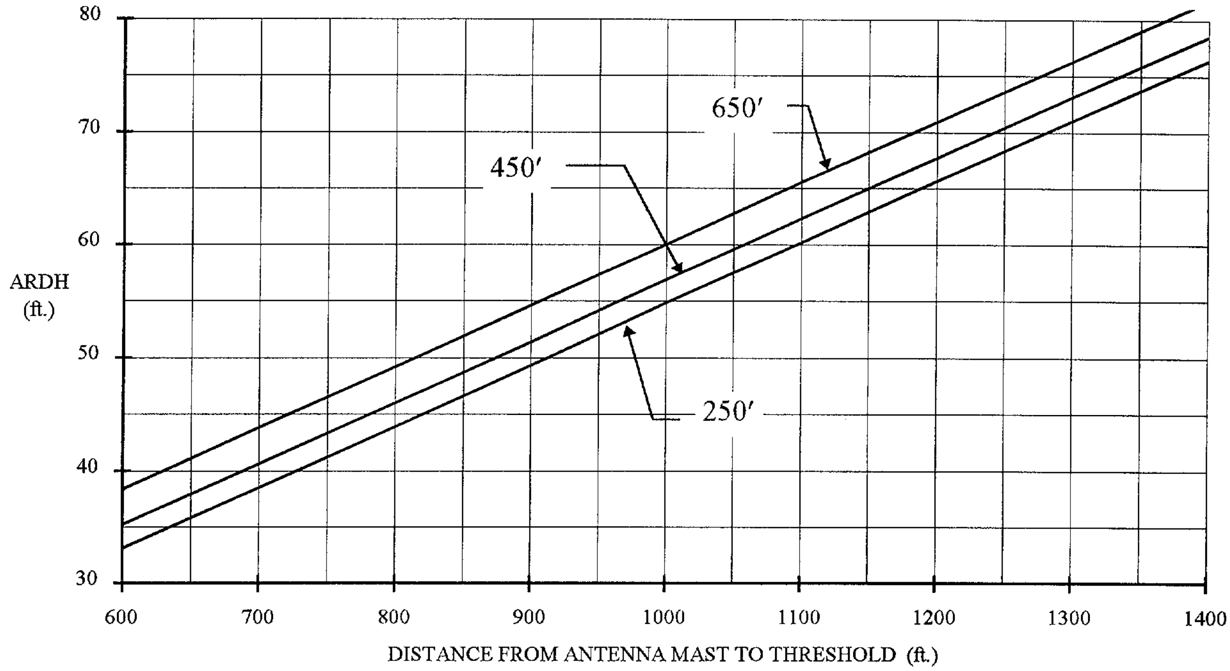


FIGURE 3. **RDH AND ARDH VERSUS DISTANCE FROM THE ANTENNA MAST TO THE THRESHOLD ALONG CENTERLINE, FOR DISTANCES OF THE ANTENNA MAST FROM CENTERLINE OF 250, 450, AND 650 FEET, AND FOR A PATH ANGLE OF 3.0 DEGREES.**



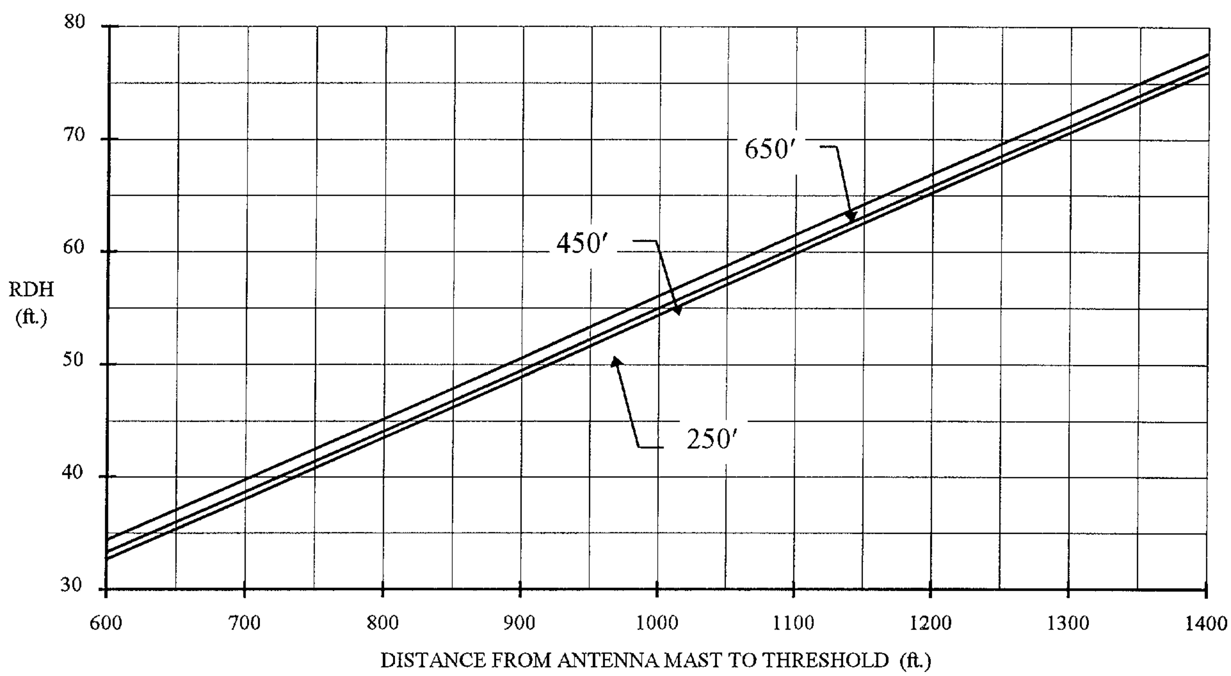
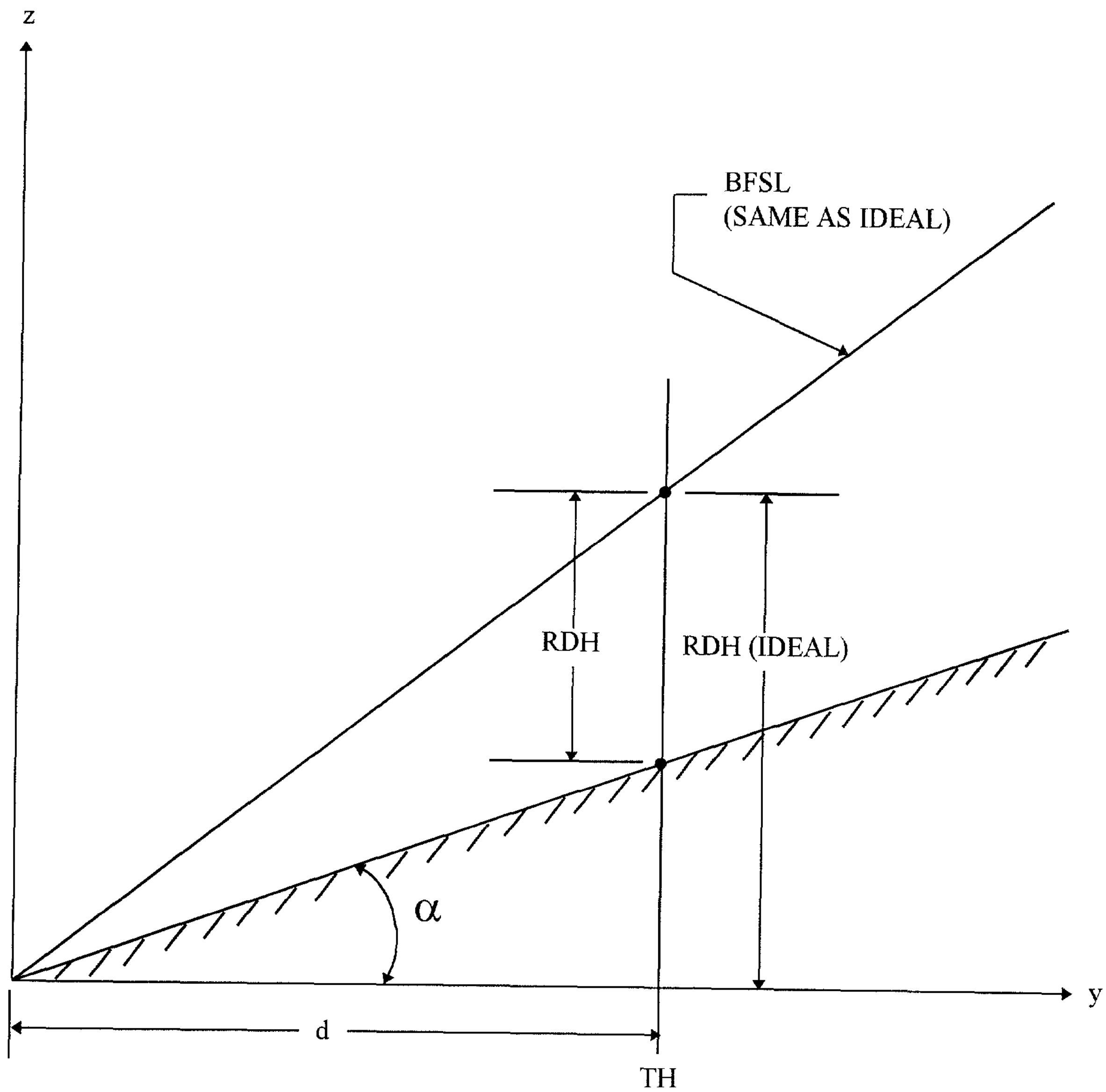


FIGURE 4. **<u>RDH AND ARDH VERSUS DISTANCE FROM THE ANTENNA MAST TO THE THRESHOLD ALONG CENTERLINE, FOR DISTANCES OF THE ANTENNA MAST FROM CENTERLINE OF 250, 450, AND 650 FEET, AND FOR A PATH ANGLE OF 3.1 DEGREES.</u>**



$$RDH = RDH\ (IDEAL) - d \tan \alpha$$

FIGURE 5. **ILLUSTRATRATION OF THE EFFECT OF A UNIFORM, LONGITUDINAL, UP-SLOPING TERRAIN GRADIENT ON THE RDH.**

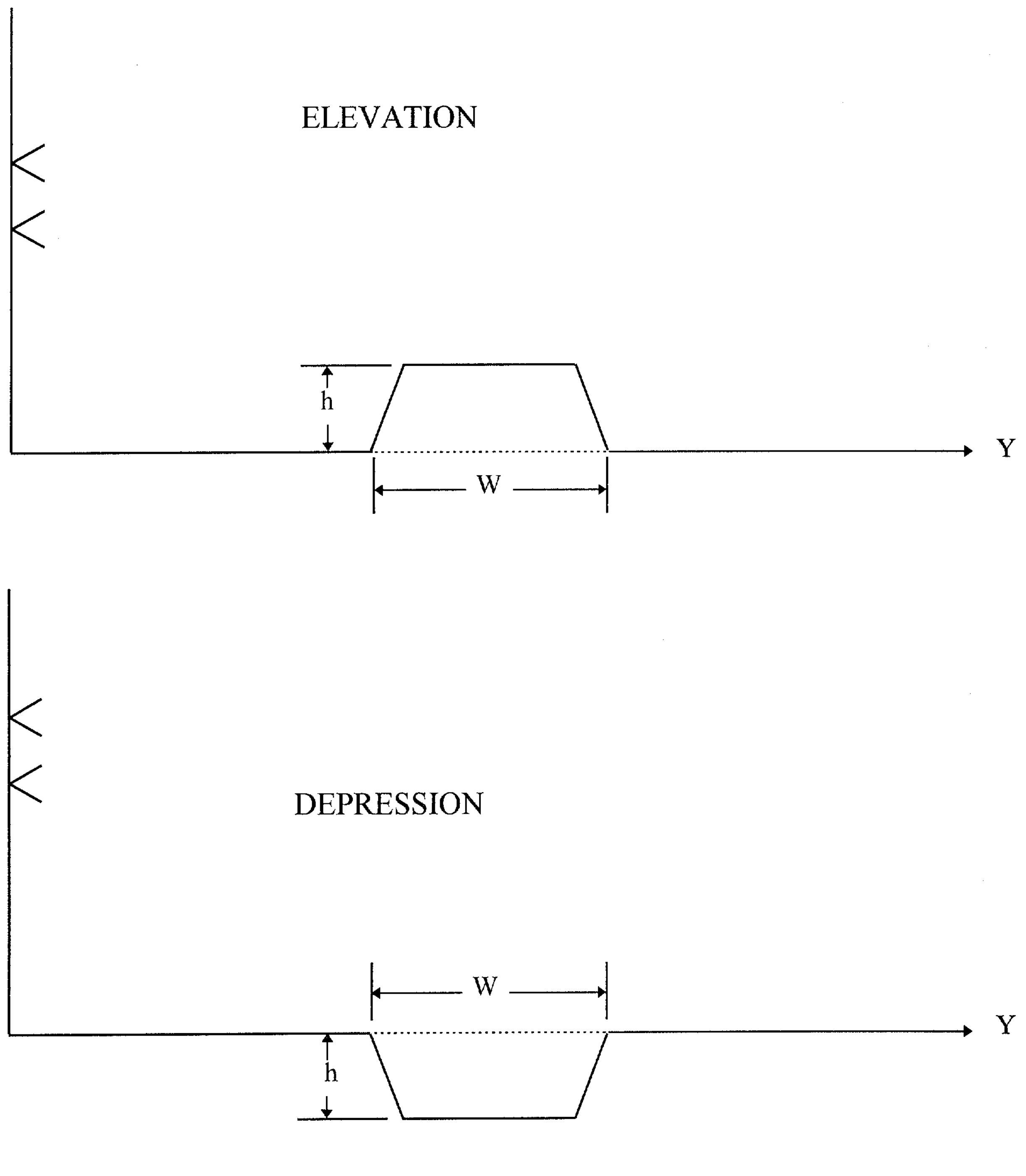


FIGURE 6. **EXAMPLES OF SIMPLE ELEVATIONS AND DEPRESSIONS IN THE TERRAIN SERVING AS THE GROUND PLANE FOR AN IMAGE-TYPE GLIDE SLOPE SYSTEM.**

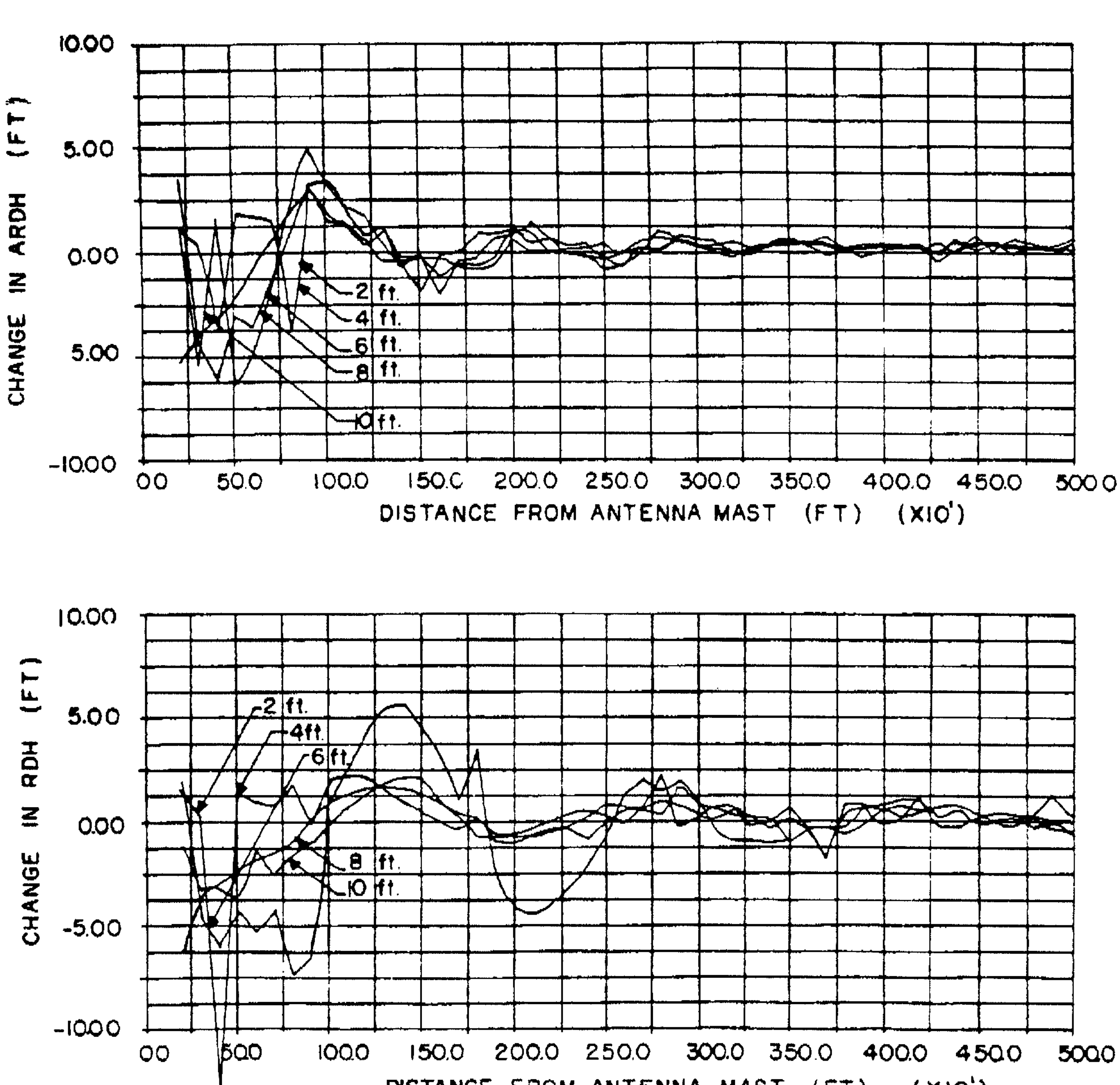


FIGURE 7. RDH AND ARDH SENSITIVITY CURVES FOR AN ELEVATED REGION OF TERRAIN, 10 FEET IN EXTENT, HEIGHTS OF 2, 4, 6, 8, AND 10 FEET, FOR A 3.0 DEGREE PATH ANGLE.

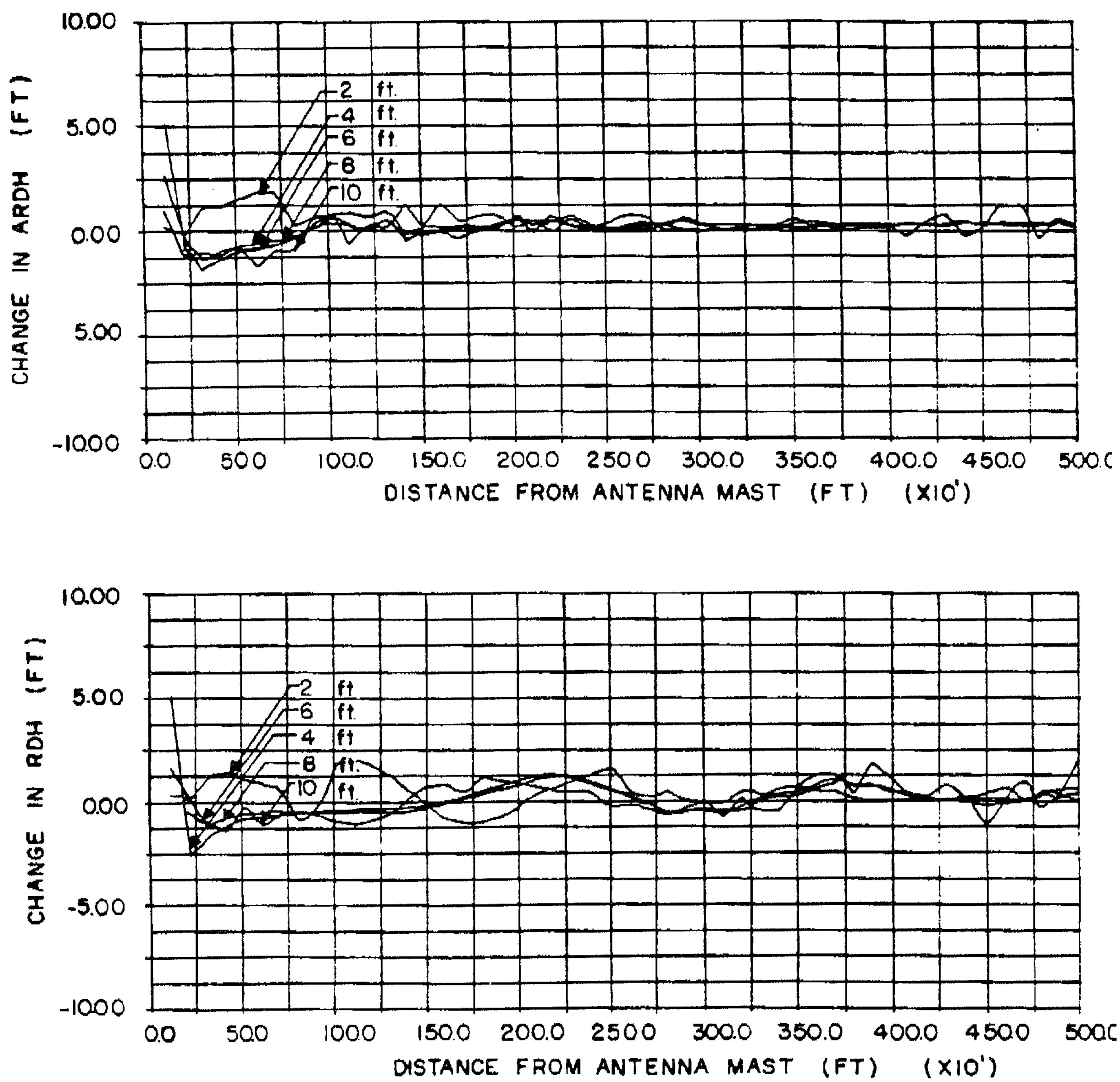


FIGURE 8. RDH AND ARDH SENSITIVITY CURVES FOR A DEPRESSED REGION OF TERRAIN, 100 FEET IN EXTENT, HEIGHTS OF 2, 4, 6, 8, AND 10 FEET, FOR A 3.0 DEGREE PATH ANGLE.

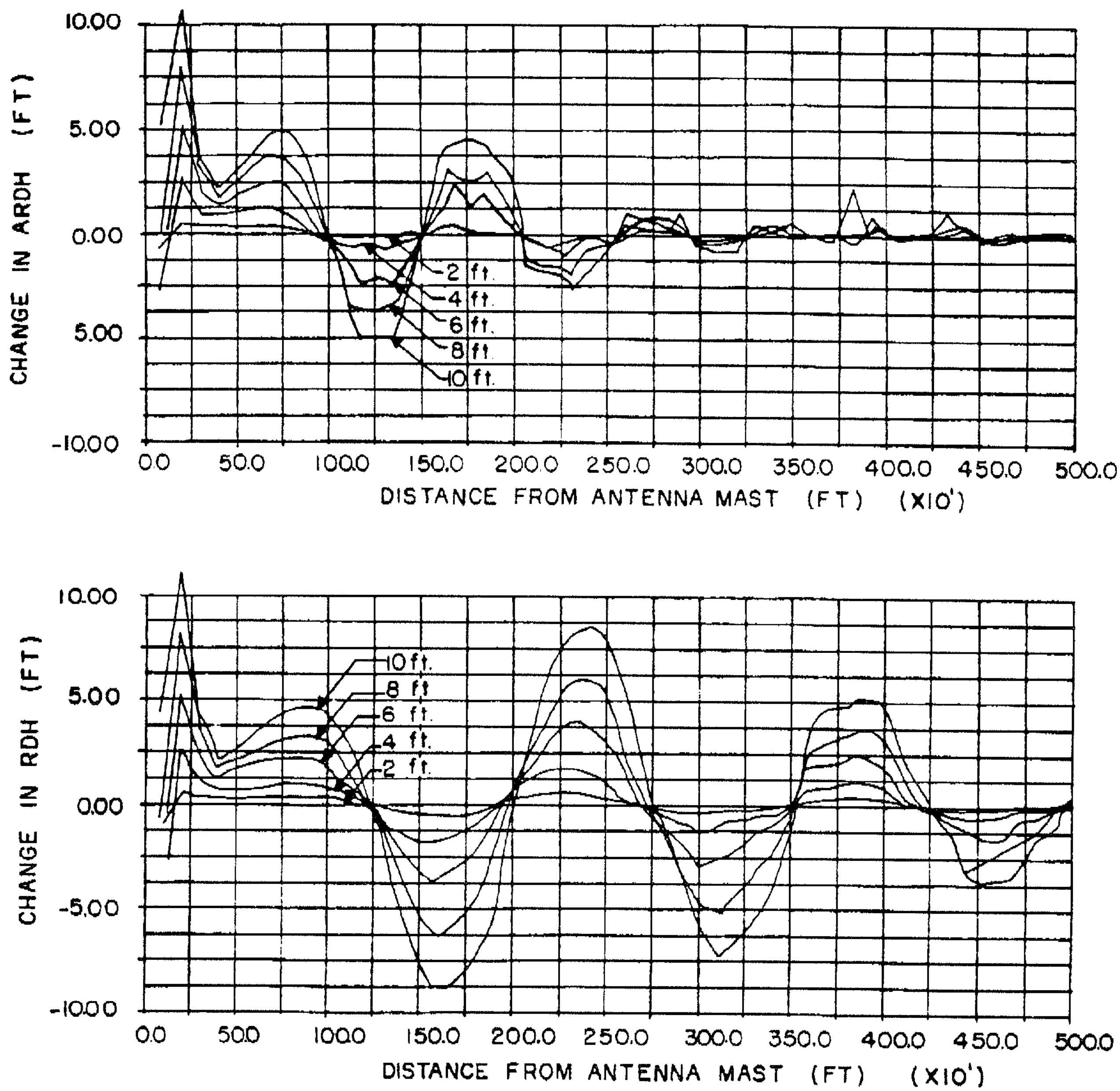


FIGURE 9. RDH AND ARDH SENSITIVITY CURVES FOR A DEPRESSED REGION OF TERRAIN, 200 FEET IN EXTENT, HEIGHTS OF 2, 4, 6, 8, AND 10 FEET, FOR A 3.0 DEGREE PATH ANGLE.

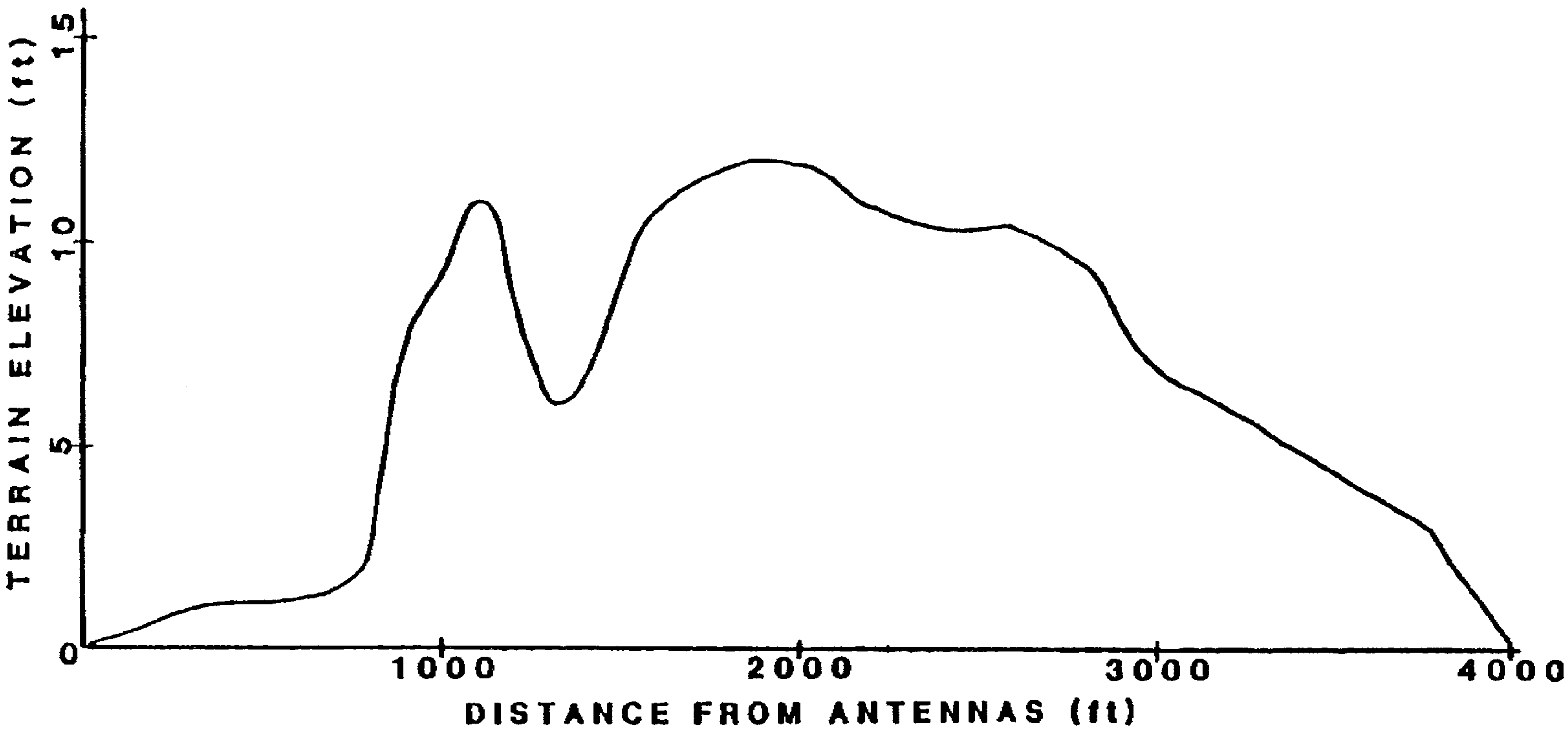


FIGURE 10. TWO-DIMENSIONAL TERRAIN PROFILE CONSIDERED IN EXAMPLE 1. NOTE THE ELEVATED REGION OF IRREGULAR TERRAIN LOCATED BETWEEN 1000 AND 3000 FEET FROM THE GLIDE SLOPE ANTENNAS.

*U.S. Government Printing Office: 1996 - 405-571/55750